An Analysis of Convergent and Divergent Instruction on the Ability of Eighth Grade Students to Understand Mechanisms

by

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ABSTRACT

The study was designed to determine the effect of convergent and divergent instruction on helping students increase their sophistication of thinking regarding mechanisms. It involved 125 eighth grade students at Kennedy Middle School in Germantown, Wisconsin during the spring of 2007.

The study was a quasi-experiment, using a non-equivalent groups design with two treatments and a control. For the pretest, students were asked to sort nine pictures of mechanisms into groups twice, each time based on a different common attribute. Sophisticated thinking was demonstrated by sorting mechanisms based on their theoretical function, while sorting based on physical attributes showed superficial thinking. Students were divided into three groups, one receiving a convergent treatment in the form of a traditional laboratory activity, one receiving a divergent treatment in the form of a design problem, and a third received no treatment and acted as the control. The activities were designed to teach students about mechanisms. Following the treatment, students received a posttest in the same manner as the pretest.

A two-way analysis of variance determined that there was that no significant effect between treatment group and their posttest scores. However, it was found that students experiencing convergent treatment were more likely to finish their activities and correctly answer culminating questions than the divergent treatment group. It was also found that females correctly answered short answer questions more often, but they did worse on the posttest than the males. These findings may be useful to teachers making judgments about how to best instruct their middle school students.

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TABLE OF CONTENTS

List of Tables

Chapter I: Introduction

Chapter one includes background information pertinent to the research. It also includes the statement of the problem and the purpose of the study. Additionally, the questions that the study intends to analyze are listed. Further, the significance of the study is outlined with assumptions and limitations. Finally, a number of terms are defined for the purpose of this study.

Background

Technology education is what has evolved from industrial arts. Content in industrial arts classes was focused around materials such as wood and metal, and students worked in the workshop creating artifacts; thus, these classes were often referred to as "shop classes," the instructors were "shop teachers," and the classes were viewed as a place for the prevocational student. Contemporary technology education challenges students to ". . . use their ingenuity with tools, materials, processes, and resources to create solutions and opportunities for themselves and others" (International Technology Education Association, n.d.,p. 2). No longer is technology education focused on the acquisition of skills, rather it is intended to give students the ability to make decisions regarding technology in whatever capacity they serve. Regardless of the changes in approach and methodology, opinions of technology education have not changed; technology education is often still viewed as shop class and it is taught by shop teachers (Lewis, 1994). The study of technology has not been given the standing as study in the areas of math, science, and literature. Lewis (1994) argued that is partly because math, science, and literature are distinct disciplines of study, while technology is a field of study much like engineering or geography, which are limitless in their range of knowledge. Regardless of the reasons technology education has been marginalized, the profession continues to push for acceptance as an integral part of a student's educational experience. In an effort to help give the study of technology large-scale creditability, the International Technology Education Association created their Standards for Technological Literacy, which outline benchmarks for students studying technology (International Technology Education Association, 2000). This document may aid in bringing clarity to administrators, teachers, students, and the general public about the profession of technology education and its goals.

These benchmarks aim to help students attain what is referred to as technological literacy. Technological literacy is defined as "the ability to use, manage, assess, and understand technology" (International Technology Education Association, 2000, p. 9). To attain technological literacy, the standards call for exploration into the nature of technology, technology and society, design, abilities for a technological world, and the designed world. Students enrolled in technology education would likely engage in a variety of activities including design and problem solving challenges which incorporate the use of modeling, they may create a poster describing the history or function of a technology, or they could take part in a simulation activity to teach them concepts pertaining to transportation or manufacturing. A technologically literate person, "understands, in increasingly sophisticated ways that evolve over time, how it (technology) is created, and how in turn is shaped by society" (International Technology Education Association, 2000, p. 9). However technology teachers decide to present their information, it is important that the instruction helps to ensure that students are attaining technological literacy and meeting the goals of the profession.

There are many different approaches that technology educators may employ to help their students achieve technological literacy. Two of those techniques include convergent and divergent instruction. Convergent instruction is a more traditional technique in which the teacher conveys information and the students passively learn (Bar-Yam, Bar-Yam, Kaput, Rhoades, & Sweeney, 2002). Students are then assessed on their ability to formulate one correct answer based on their background knowledge, typically in the form of a formal assessment. Divergent instruction is designed to be learner focused; typically, a problem is presented and students are encouraged to gather information using any means while providing many solutions. Students are assessed based on the learning process and the creativity of their ideas as opposed to their ability to produce a single correct answer. Convergent instruction has been used in technology education classrooms for many years, and divergent instruction is beginning to see more implementation as teaching design becomes a main focus of technology education. Thus, it is important to consider the role that each instructional methodology may play in the ability to help students attain technological literacy.

Mechanisms are defined as "a machine or mechanical appliance" ("Mechanism", n.d.). Mechanisms are the individual parts that work together to create mechanical systems. Mechanisms can be categorized in two ways, based on their physical attributes or based on their theoretical function as distance multipliers, force multipliers, or balanced mechanisms. Sorting mechanisms by physical attributes demonstrates superficial thinking because a person need not understand the purpose of the mechanism to accomplish this; however, categorizing mechanisms based on theoretical function demonstrates sophisticated thinking because a person must understand the purpose of the mechanism.

Statement of the Problem:

Living in a technological society, technological literacy takes on great significance. It is important to consider how various forms of instruction, in this case convergent and divergent, affect students' ability to understand mechanisms.

Purpose of the Study

This study is designed to consider the effect of convergent and divergent instruction on the ability of eighth grade students at Kennedy Middle School in Germantown, Wisconsin to demonstrate the sophistication of their understanding of mechanisms during the spring of 2007.

Research Questions

This study attempted to answer the following questions:

1. What effect does convergent lab activity have on students' sophistication of thinking regarding mechanisms?

2. What effect does the completion of a divergent lab activity have on students' sophistication of thinking regarding mechanisms?

3. What is the difference in students' sophistication of thinking regarding mechanisms relative to their completion of a convergent lab activity versus completion of a divergent lab activity?

4. What effect does gender have on students' sophistication of thinking regarding mechanisms?

Significance of the Study

Because of the increasingly technologically sophisticated society in which we live, the need for students to be technologically literate is more important than ever (International Technology Education Association, 2000). Part of attaining technological literacy is the ability to consider technology in a systematic manner. Organizing technological concepts based on various criteria tests one's understanding of a concept. Considering the broad use of convergent teaching methods in technology education and the recent focus on using divergent teaching methods in the realm of design, it is worthwhile to consider which will help students to best gain an understanding of mechanisms.

Assumption

This study assumes that reading scores are an appropriate measure to prove the treatment groups were as analogous as possible.

Limitation

The limitation of this study is that the sample was limited to eighth grade students at Kennedy Middle School in Germantown, Wisconsin. Therefore, results may not be generalizable to other populations.

Definitions

For the purpose of this study the following terms were used as defined:

Attributes of mechanisms: Mechanisms classified by their physical characteristics.

Balanced mechanisms: Input and output forces and distances are the same. For this study, balanced mechanisms included arrangements using gears of the same size, pulleys of the same size and a lever with its fulcrum in the center.

Convergent instruction: Traditional instructional methods in which instruction is teacher driven and content is presented in an explicit fashion.

Convergent thinking: A way of thinking in which the problem solver calls on previously learned knowledge to create a single best and correct answer or solution to a problem.

Convergent treatment: A hands-on instructional experience in which students were given a bag of mechanisms and a packet that directed them to perform various steps in a prescribed order. As they progressed through the learning activity they were asked to answer multiple-choice questions related to their experience

Distance multipliers: When a modest amount of input distance put into a mechanism gives greater output distance. For this study distance multipliers included arrangements where the cranking gear was larger than the lifting gear, the cranking pulley was larger than the lifting pulley and the lever's fulcrum was nearest to the input force.

Divergent instruction: A method of instruction in which a problem is presented and the student is called upon to produce as many solutions as possible, by whatever means possible, to come to a logical answer or solution. The process is student centered and arranged in a non-linear fashion.

Divergent thinking: A way of thinking in which the problem solver begins with the problem and elaborates on it to develop many possible answers or solutions to a problem.

Divergent Treatment: A hands-on instructional experience in which students were presented with a bag of mechanisms, a design problem was posed and the students were asked to furnish a complete solution to the problem without any direction. They were required to sketch ideas prior to building, and they were asked open-ended questions related to their experience.

Explicit Instruction: Instruction that is laid out step by step, following a logical or linear sequence (e.g. simple to complex, concrete to abstract).

Force multipliers: When a modest amount of input force put into a mechanism gives greater output force. For this study, force multipliers included an arrangement where the cranking gear was smaller than the lifting gear, the cranking pulley was smaller than the lifting pulley and the fulcrum on the lever was closest to the weight.

Sophisticated Thinking: Thinking in a way that demonstrates understanding of conceptual meaning. For the purpose of this study, sorting mechanisms based on theoretical attributes as being balanced, distance multipliers, or force multipliers was considered sophisticated thinking, because a person must understand the theoretical principles of mechanism function to sort in this manner.

Superficial Thinking: Thinking that is disconnected from deep meaning or understanding. For the purpose of this study, sorting mechanisms based on physical attributes is considered superficial thinking. To sort based on physical attributes one need not understand anything about the function of mechanisms and can rely on the cues in the pictures (Glaser, 2003).

Theoretical function of mechanisms: Classifying mechanisms based on their function as balanced mechanisms, distance multipliers or force multipliers.

Mechanisms: For this study the following simple machines were used to represent mechanisms: levers, gears, belts and pulleys.

Chapter II Review of Literature

The purpose of this study was to understand the role that convergent and divergent instruction play in the students' ability to understand mechanisms. Technology education uses the study of mechanisms as a gateway to help students become technologically literate. Therefore, technological literacy and its importance were explored. In order to learn students, must be able to consider new ideas and concepts and compare them to what they know. This process was examined through reviewing literature on cognitive learning. When students are confronted with a problem to solve, they must search their memory to construct a solution. The way in which they construct that solution and the type of solution they furnish can be dependent on the way they think or the way in which they were taught. Therefore, the literature review looked at the role of divergent and convergent thinking and convergent and divergent teaching methods in education. Additionally, consideration was given to the role that mechanisms play in educational curriculum. The literature review also dealt with the differences in the ways males and females perform in technology education classroom, as well as their attitudes towards technology.

The Cognitive View of Learning

In the study of psychology, the concept of learning is greatly examined and also quite controversial. Two of the main viewpoints are those who believe learning occurs behaviorally and others who suggest it is a cognitive endeavor. The behaviorist believes learning is the acquisition of new behaviors (Pritchard, 2005). A person's behavior is the result of a presented stimulus, and a change in stimulus should result in behavioral change. Thus, a change in behavior is evidence of learning. Behaviorists discount the role of mental activity and center on observable behaviors. Those who believe that learning is a cognitive function consider learning to involve the acquisition, organization, storage, and retrieval of knowledge (Woolfolk, 1998). Learning is the result of a person's attempt to make sense of the world based on what is known and what is experienced. Cognitive learning theorists focus on the mental maps a person makes to construct meaning.

Cognitive psychologists believe that learning occurs when people acquire new knowledge and use that knowledge to create new understandings and connections among concepts that are already held in memory (Woolfolk, 1998). Jean Piaget, a well-known cognitive psychologist, theorized that humans' ability to learn occurs in stages as a person develops. According to Piaget, humans go through four stages of development. First is the Sensory-Motor stage during the ages of 0-2. Children at this stage only understand what they are experiencing; they do not have knowledge of language and only understand the world from their point of view (Hergenhahn & Olson, 1997). At the end of this stage, children develop the understanding that objects continue to exist even when they cannot be seen. From ages 2-7, children are in the Pre-operational stage. At this point, children begin to create mental imagery (Pritchard, 2005). Specifically, they begin to connect objects with words. The third stage is the Concrete Operational stage, which typically occurs between the ages of 7 and 11. During this stage, children begin to understand problems from other points of view; however, their ability to solve problems depends on the problem's level of abstraction. Children at this stage can deal only with concrete concepts. Also at this stage, students begin to be able to solve problems intuitively (Hergenhahn & Olson, 1997). For instance, a child seeing two identical containers with equal amounts of water poured into two dissimilarly shaped containers realizes that the containers still contain equal amounts of water. The final stage, from 11 on, is called the Formal Operations stage. At this stage, humans can embrace the abstract and think hypothetically. Upon reaching this stage, a person's thinking mechanism is as advanced as it will be. However a person's ability to solve problems is based on held knowledge, which continues to grow.

Of great importance to the growth of knowledge is the concept of schema. According to Woolfolk (1998), schemata (plural of schema) are "abstract knowledge structures that organize vast amounts of information" (p. 259). Schemata help us to organize our memory, categorize attributes of objects and concepts, and recognize links and similarities between concepts. Schemata is responsible for filing knowledge, and it is the way in which this knowledge is filed that allows us to be able to properly make inferences and construct meaning (Bruning, Schraw & Ronning, 1999). The way in which a human acts in relation to his or her surroundings is directly attributable to the schemata he or she holds. When humans are confronted with a new concept, object, or idea, immediately they scan their held schemata to try and create an understanding. Often times, this new concept will require some type of change. According to Piaget, we deal with these new concepts through assimilation or accommodation (Hergenhahn & Olson, 1997). As humans we desire to survive. Therefore, we must make sense of the world to survive. When confronted with new ideas or objects, we must learn about them and understand how they fit into our environment. When humans assimilate these new concepts or objects the knowledge is simply added to our schemata (Pritchard, 2005). However, with this simplistic addition of knowledge, the bank of our knowledge would not only become enormous, but contradictions would begin to occur (Hergenhahn &

Olson, 1997). Therefore, the accommodation of knowledge occurs when our mental structure is altered to respond to the new knowledge (Pritchard, 2005). Piaget referred to the force which drives us to assimilate and accommodate new information so that what is experienced, and what is known, are in harmony as equilibration.

Learning and the growing of schemata is a complex process, studied by psychologists who have created the information processing theory. The information processing theory considers the way in which humans take in, evaluate, store, and retrieve information (Woolfolk, 1998). To explain the process by which information is received, stored, and used, psychologists created the information processing model. The basis of this model is that when information is processed, meaning is evaluated, and information that does not hold meaning is lost along the way. When a person is confronted by new information, it enters through what is referred to as sensory memory. Sensory memory is where the initial screening of information occurs, that which is worthy moves on, that which is not is forgotten (Bruning, Schraw & Ronning, 1999; Woolfolk, 1998). Worthy information is then sent to short-term or working memory where it is scrutinized once again. At this stage, information from the final stage, long-term memory, is retrieved and the ability of the new information to offer value based on held knowledge is considered. Valuable information is then stored in long-term memory, where it is held until it is activated again by working or short-term memory. Much like describing computer processing, the terms of encoding, storage and retrieval are used. Encoding occurs when information is given meaning, storage is holding information, and retrieval refers to reconstructing or accessing the information held in storage.

Convergent Thinking and Teaching

Convergent thinking is typically associated with linear, structured reasoning. It is a method in which one draws upon their held knowledge and processes it to create a single logical answer or solution (Atherton, 2005). When discussing the attributes of convergent thinking, Arthur Cropley (2004) stated, "It emphasizes speed, accuracy, logic, and the like, and focuses on accumulating information, recognizing the familiar, reapplying set techniques, and preserving the already known" (p. 4). Convergent thinking is most effective when there is one best answer or the answer is easily constructed through the application of logic or explicit strategies and methodologies. The results of convergent thinking are completely shaped by the criteria set forth in the problem (Guilford, 1968), and are based on factual knowledge; therefore the answer or solution should be verifiable (Agogino, Dym, Eris, Frey & Leifer, 2005). Also, the result of applying convergent thinking is a solution that generates "orthodoxy" (Cropley, 2005, p. 4). The use of convergent thinking is typically required on standardized tests in which one correct answer is sought, or on tasks such as outlining where concepts are structured in an understandable and logical fashion (Thomson, 2001; Zent, 2001).

Teaching through the use of convergent instruction is familiar to most teachers and students. In convergent teaching, the focus is on transmission of knowledge from the teacher to the students, and it is structured in a way that the teacher is the focus of attention and the students are passive recipients of the knowledge set forth by the teacher (Bar-Yam, Bar-Yam, Kaput, Rhoades & Sweeney, 2002). In a classroom using convergent instructional methods, students are focused on learning a specific bit of knowledge in the same manner; which leads to some students achieving success while others fail.

Divergent Thinking and Teaching

Divergent thinking is associated with the generation of various answers or solutions through any means possible. When a person uses divergent thinking, he or she starts with a stimulus, typically a problem or question, and generates as many possible answers or solutions as he or she can (Atherton, 2005). Cropley (2004) described divergent thinking in this manner, "It requires making unexpected combinations, recognizing links among remote associates, transforming information into unexpected forms, and the like" (p. 4). Divergent thinking concerns itself with concepts as opposed to facts, therefore solutions and answers should be logical, but not necessarily verifiable (Agogino, Dym, Eris, Frey, & Leifer, 2005). Where convergent thinking strives for a single best answer, divergent thinking seeks many answers without judgment on which is correct; the results of divergent thinking produce "variability" as opposed to "orthodoxy" (Cropley, 2004, p. 4).

J.P. Guiford (1968) studied creativity extensively. He described divergent thinking in four parts: fluency, flexibility, originality, and elaboration. Fluency involves generating a large number of ideas, flexibility is about producing a variety of ideas, originality is about constructing new and fresh ideas, and elaboration is about adding to existing ideas (Lewis & Zuga, 2005). Fluency may have the biggest impact on students' ability to classify.

> A fluent thinker is one who can run through the logical possibilities or logical alternatives in quick fashion. His processes of retrieval work efficiently. The

> kinds of products involved in connection with the three fluency factors are units, relations, and systems. A unit is a segregated 'chunk' of information that we conceive of as being separate and distinct from other information and having internal cohesiveness. A relation is some kind of conceived connection between two items of information. A system is some interlocking, organized, or structured combination of items of information. (Guilford, 1968, p. 125)

Divergent thinking may help students to create understandings that will assist them in sorting concepts into categories.

When a person uses divergent thinking, they are accessing stored information in their memory in ways different from someone who uses convergent thinking. When a person is confronted with a cue, memory recall occurs (Guilford, 1967). For instance, a child may hear their parent say hot, and they will remember the stove on which they burned themselves. As a person stores more in their memory, cues will elicit a greater number of responses. To make the recall of memory efficient, a person creates a "search model" that guides memory recall (p. 214). The divergent thinker will be confronted with a cue and memories will be called up which may have been associated directly with that cue when learned, but what sets that thinker apart from the convergent thinker is the ability to create new associations between cues and memories. For instance, if someone asks a convergent thinker to come up with three uses for a brick, they may respond that it could be used in building a house, making a sidewalk, or creating a retaining wall. All three have to do with building, because when the concept of a brick was stored in that person's memory, the person learned it to be a building material. A divergent thinker asked the same question, may give an answer to build a house, but is also more likely to say use it as a paperweight or to drive a nail. Even though the concept of brick was likely stored in this person's memory as a building material, the divergent thinker has the ability to take a concept or a cue and create new or different associations. This trait is referred to as flexibility, and a person who uses divergent thinking to solve problems is more comfortable considering a greater number of associations between cues and the memories they recall. (Guilford, 1968).

According to Bar-Yam, Bar-Yam, Kaput, Rhoades, & Sweeney (2002), teaching using divergent instructional methods is more learner focused than convergent methods. The divergent approach involves more flexibility and encourages students to be an active part of the learning process, with achievement being measured by a variety of tools such as portfolios, self-evaluation, and projects. Divergent teaching desires to help students become self-directed learners who can eloquently articulate themselves. Divergent instructional methods are appropriate for almost any subject and are a break from more traditional convergent instructional methods. Divergent instructional methods are especially useful for design and problem-solving activities (McCade, 1990). Divergent instruction allows students to take ownership of the problem, develop their own approach to solving it, and requires them to fill in holes in their understanding of concepts on their own accord.

The Relationship between Divergent & Convergent Thinking and Teaching

Some see divergent thinking as creative thinking and consider convergent to be just the opposite. However there seems to be a relationship between the two that is very important. Essentially, the ability to produce ideas or answers, whether numerous or singular, requires memory recall, and both convergent and divergent thinking rely on what is stored in memory (Guilford, 1967). Therefore, regardless of the path one takes to furnish an idea or solution, convergent thinking or divergent thinking, the starting point for the journey is what is stored in memory. And while the path for presenting ideas and solutions using convergent thinking is very structured, leaving no room for error and thus limiting the number of possibilities or solutions to one, convergent thinking is an important part of creating logical solutions. Sutherland (1996) in The International Dictionary of Psychology listed convergent thinking as "Thinking in the controlled analytic way needed for problems that can be solved algorithmically; such thinking is also needed in other problems to test whether the solutions provided by divergent thinking actually work" (p. 101). Divergent thinking may result in many unique and unthought-of solutions or answers, but if they are not logical or possible, they are useless and it takes convergent thinking to evaluate their usefulness (Cropley, 2004). Guilford (1967) states, "Convergent production rather than divergent production is the prevailing function when the input information is sufficient to determine a unique answer" (p. 171). There is a debate as to whether quality of ideas or quantity of ideas is more important. Some say quantity breeds quality, while others argue that quantity waists time with many low-quality answers (Guilford, 1968). Evaluation and judgment are used when a person recalls a memory and fashions a response to a question or problem; however, those that more typically use divergent thinking often withhold judgment of ideas until later in the process, thus producing a larger variety of ideas. The convergent thinker evaluates ideas immediately resulting in fewer answers. There is a balance between the two types of thought that is delicate, as evaluation too early would result in common and boring ideas, while invoking no sort of evaluation would result in low-quality ideas that lead to inefficiencies in the idea generation process.

Teachers must be sensitive to the balance needed between convergent and divergent thinking. Agogino, Dym, Eris, Frey, and Leifer (2005) in their narrative Engineering Design Thinking, Teaching, and Learning, spoke of the interaction between convergent and divergent thinking in this way:

> Therefore, effective inquiry in design thinking includes both a convergent component of building up to asking deep reasoning questions by systematically asking lower-level, convergent questions, and a divergent component in which generative design questions are asked to create the concepts on which the convergent component can act." (p. 105)

Students must have knowledge to draw from to create meaningful solutions, and without basic knowledge and skills, there is no ability for the student to be self-expressive (Bar-Yam, Bar-Yam, Kaput, Rhoades, & Sweeney, 2002). The future of education is likely to become increasingly complex, and educators will have to embrace both convergent and divergent instructional approaches, as they are apt to ". . . become not mutually exclusive but interrelated and interdependent" (Bar-Yam, Bar-Yam, Kaput, Rhoades, & Sweeney, 2002, p. 1).

Mechanisms in Technology Education Curriculum

The study of mechanisms offers very rich insight into many complex and diverse systems and is an appropriate part of technology education. Relating to the benefits of studying mechanisms, Parkinson (1999) said, "At a conceptual level mechanisms are part of our technological society and embrace core ideas on the transfer of energy and the application of force. Engagement with mechanisms in school settings can be one of the very practical routes by which scientific understanding can be gained through interaction with technology." (p. 2)

The study of mechanisms in technology education can help students to understand how motion is transferred, energy is spent and conserved, and offers excellent cross-curricular learning opportunities. The International Technology Education Association (2000) mentions the role and value of teaching mechanisms to technology students in their publication Standards for Technological Literacy. In this publication, readers are offered an exemplary example of an articulated curriculum in the area of transportation. This example calls for students to begin an exploration of mechanisms as early as kindergarten. Students in third grade should be able to create a vehicle that incorporates one mechanism. By fifth grade, their vehicle should incorporate three or more mechanisms. As students mature, the benefits of studying mechanisms increase as they begin to bring math, science and other subject areas into their exploration. Students should be expected to use mechanisms in interesting and innovative ways to solve posed problems. Likewise, the British, who have long had an emphasis on design and technology in their national curriculum, focus on the teaching of mechanisms (Qualifications and Curriculum Authority, 2006). The Qualifications and Curriculum Authority outlined four key stages for children's academic progress throughout their educational experience. The national curriculum specifies the curricular foci for students at each of these key stages divided by content areas. One of the content areas is Design and Technology. This portion of the National Curriculum instruction, the study of mechanisms is specifically called for during both key stages one and two. Key stages three and four also call for the incorporation of mechanisms as part of the study of systems.

Other academic subjects also refer to the study of mechanisms in their standards. An example of this is noticed in the National Science Education Standards, which outlines many different areas of science that should be taught, one of which is physical science (National Academies Press, 2006). One of the components of physical science is to understand motion and energy.They suggested that students should observe moving objects such as toys to better understand how force is transferred and energy is used in their standards for students in grades K-4. Clearly, the mechanisms used in these types of objects can help to solidify students' understanding of physical science principles. The study of mechanisms should be a part of a student's academic experience, and belongs in the technology education curriculum.

Technological Literacy

The study of technology should lead to some end technological literacy. Creating students who are technologically literate is the goal of technology educators. In general, literate people can be considered as a group of people who share a common body of knowledge which allows them to communicate and understand each other and the world around them (The National Academy of Sciences, 2006). Therefore, technological literacy involves groups of people sharing common knowledge about technology. The International Technology Education Association (2000), in their publication, Standards for Technological Literacy, defines technological literacy as:

". . . the ability to use, manage, assess, and understand technology. A technologically literate person understands, in increasingly sophisticated ways that evolve over time, what technology is, how it is created, and how it shapes society, and in turn is shaped by society . . . A technologically literate person will be comfortable with and objective about technology, neither scared of it nor infatuated with it (pp. 9-10)."

A technologically literate person understands technology and feels comfortable with its presence and his or her ability to live in a technological society. According to The National Academy of Science (2006), technological literacy embodies three distinct dimensions, including knowledge about technology, ways of thinking and acting toward technology, and capabilities when interacting with technology. Some people may be very capable in dealing with technology, but struggle to think objectively about technology and its impacts. To be technologically literate, a person should be knowledgeable about technology, think and act objectively when confronted with technological issues and work to become sufficiently capable in dealing with technology. Technological literacy is important socially and individually. Students must understand the broader social implications of technology (Saskatchewan Learning, 2006). Technology and technological issues are important influences on politics, culture, and economics. From power plants to cleaning chemicals, technology shapes and is shaped by society, and citizens must have the ability to create a value system which guides their thought processes on technological issues. Considering that our society is democratic and individuals help to shape policy regarding technology, better informed and more rationale decisions will likely be made if citizens are technologically literate (Drugger, 2001).

Also, technologically literate students are better poised for success as citizens, employees, and consumers. When a person shops for a new technological gadget, they are better prepared to understand the differences and tradeoffs between what is available. When their employer asks them to learn to operate a new computer program, they are not anxious about the challenge. Moreover, when they are sitting in a county board meeting, they can speak articulately regarding the proposed change.

The role of gender in Technology Education

Persuading female students to enroll in technology education is a quandary that has been considered by many technology education professionals. There are many issues at play in the decision of females to stay away from technology education courses. One of the issues is a social one. Our culture has a tradition of male dominance, with a history of marginalizing the role of women (Zuga, 1999). From the language used in literature to the casting of the illogical or mystical as feminine, women's abilities have often been misunderstood. Furthermore, our society places much emphasis on gender roles. Consider children's toys; girls play with dolls and pretend kitchens, while boys play with Legos and cars (Wisconsin Department of Public Instruction, n.d.). Students are given messages from their family, the media, and their communities as to what appropriate interests and careers are for men and women. Oftentimes, careers in technology are not part of the message for young women. Another issue is the differences in the ways males and females think about technology. Females often prefer to consider the social impacts of technology, while males often prefer the technical (Custer & Weber, 2005). The Wisconsin Department of Public Instruction (n.d.) said this about female's views of technology, "Girls and women see it as a means of facilitating collaboration, communication, and linkages between people. Boys and men tend to see technology as a means of extending their control over the physical environment" (p. 3). Because males traditionally take technology education classes, curriculum has been developed around their interests; in other words, curriculum often focuses on the technical aspects of technology without consideration for the affective side of technology (Zuga, 1999). Thus, the curriculum does little to attract females. Curriculum today focuses greatly on competition and making things work, however, females often prefer collaboration and helping people (Custer & Weber, 2005).

Furthermore, teachers may be creating an environment of gender bias without realizing it. Females typically need a higher degree of explanation and contact with the teacher, they like to talk it out, but this takes a great amount of the teacher's time and makes the instructor vulnerable as they must divulge that which makes them the expert (Zuga, 1999). Other factors also play into many females decisions regarding technology education. A lack of structure in the classroom can lead to the domineering males to hog tools and supplies (Parrish, 2001). Furthermore, gender biased jokes or comments are often made and thus a hostile environment for females is created. Typically, females also come at a disadvantage having had less exposure to tools and materials. The stigma of the dirty shop remains embedded in many people's minds, and messages from counselors are not ones of encouragement for females in technology education (Wisconsin Department of Public Instruction, n.d.). While technology education is taking steps to create a more female friendly environment, historically technology education has lacked important female involvement as a field.

Chapter III: Methodology

This chapter will discuss the methodology used to conduct the research. First, it will explain the population and sample of the study. Secondly, it will explain the research design. Next, it will explain the pretest, convergent treatment, divergent treatment, control, and posttest. After that, the instrumentation for the study will be discussed. The subsequent topic will be the analysis of the data collected. Then, chapter three describes the procedure used to collect the data. Further, the limitation of the methodology will be discussed.

Population and Sample

The population included was all eighth grade students at Kennedy Middle School in Germantown, Wisconsin who elected to take technology education courses. Eighth grade students at Kennedy Middle School who were enrolled in the researcher's first and second hour "blue day" and first and second hour "gold day" technology education classes during the spring of 2007 were included in the sample (see appendix A for further explanation of schedule). The researcher's colleague's first and second hour "gold day" and the first hour "blue day" classes served as the control group for the study. Subjects were assigned to classes based on their choices a year prior; therefore, random assignment was not possible.

Research Design

The study was a quasi-experiment, using a non-equivalent groups research design with two treatments and a control. A pre-test was administered to the entire sample. One group received treatment A in the form of convergent instruction. Another group of students received treatment B in the form of divergent instruction. A third group of students received no treatment and acted as the control. All students were then administered a posttest. The pretest and posttest performance of each treatment group was evaluated to determine if the treatment had any significant effect by group.

The dependent variable in this study was the type of thinking students applied to the sorting process. Students sorting the pictures of mechanisms based on physical attributes or some other characteristic showed superficial thinking, while those sorting based on theoretical function showed sophisticated thinking. The independent variables included the type of treatment the student received as well as the gender of the student.

To ensure the treatment groups were as analogous as possible, subjects were assigned to treatment groups based on their sixth grade Wisconsin Knowledge and Concepts Examinations (WKCE) reading scores. All students who received treatment were ranked according to their score. Of the two students who scored highest on their reading test, one was assigned to the convergent treatment group and the other was assigned to the divergent treatment group. The next two highest scorers were assigned to treatment groups using the same method. This pattern was continued until all students were assigned to a group. Students without a score were randomly assigned. This process was not used with the control group.

Pretest

The entire sample received the pretest. Students were given instructions on how to complete the instrument using a pre-recorded video of the researcher explaining the sorting process (see instrumentation section for more explanation of the instrument used). The video included an example of sorting using salty, cheesy, and spicy snacks (see appendix M). Following the instructions, the instrument was handed out to the participants. Participants completed the instrument and turned it in to the researcher. Then, a second copy of the instrument was handed out and participants were asked to complete it. The researcher then scored the instrument.

Convergent Treatment

Those students in the convergent treatment group were presented a very traditional laboratory experience in which they were given a teacher-formatted, self-guided packet with a series of steps leading to a final understanding about mechanisms (see appendices D, E, and F). The instruction was delivered in a very teacher driven way and the knowledge was gained in a clearly prescribed path. The packets gave specific instructions as how to arrange the mechanisms. Each day, participants explored gears, levers, and belts and pulleys. Due to the limitations of the resources, one third of the students were randomly scheduled to engage in the gear activity first, another third received the belt and pulley activity first, and the final third received the lever activity first. A rotating schedule was created to rotate the mechanisms among the students to ensure equal engagement with each. The packets directed participants to create balanced mechanisms, force multipliers and distance multipliers; they were also required to complete pointed multiple-choice questions related to their experiences.

Divergent Treatment

Those students assigned to the divergent treatment group were presented a design activity that was created to be very student driven, and involved non-prescribed methods to build their understanding about mechanisms. Whereas the traditional lab started with nothing and took methodical steps to build a final understanding, the divergent activity presented students with the criteria of a complete solution posed in the form of a design problem and relied on the student to create a solution that meet those criteria without any guidance (see appendices G, H, and I). Each of the three days was devoted to a different topic including gears, levers, and belts and pulleys. Each day, participants were given a packet and a bag of materials related to the topic of the day. The group was randomly divided into thirds and scheduled to complete the laboratory activities in the same manner as the convergent treatment group. Each topic embodied three different design problems, each with specific criteria requiring them to create a balanced mechanism, distance multiplier and force multiplier. Participants were asked to sketch their ideas in the packet prior to physically trying them. After successfully completing the design problem, students were asked to complete three open-ended short answer questions related to their experience.

Control

The pretest was administered to the control group. They, then, received no treatment. After the other two groups completed their treatments, the control group was administered the posttest. Furthermore, the curriculum in these classes did not include the study of mechanisms.

Posttest

The treatment lasted for three instructional periods, and after all treatment was completed, the entire sample was administered a posttest during a fourth instructional period. The posttest was administered using the exact same methods and materials as the pretest (see instrumentation section for more explanation of the instrument used). Following the administration of the posttest, participant performance was evaluated and the study was complete.

Instrumentation

The instrument was intended to gather data regarding students' sophistication of understanding regarding mechanisms. The instrument consisted of nine pictures, including pictures of gears, belts and pulleys, and levers arranged as balanced mechanisms, distance multipliers and force multipliers (see appendix C). It also included an envelope, three paper clips and a note card. All of the contents were housed inside of the envelope, and the envelope was labeled with the student's name and number. The participants were then instructed to sort the nine pictures into three groups based on some type of organizing characteristic. After the students sorted the pictures, they were asked to paperclip the piles together, write a modest explanation for their sorting strategy on the note card and put all of the contents into the envelope. Following this, they were given a second set of the same materials and asked to repeat the process, only using a different defining characteristic. The instrument was used during the pretest and again during the posttest.

Data Analysis

Each instrument was analyzed for evidence of sophisticated thinking (see appendix N). Each picture had a possible score of one. To earn a score of one, the student sorted that picture based on its theoretical function. Sorting the picture any other way resulted in a score of zero. Students could receive a maximum score of nine, meaning all nine pictures were sorted based on their theoretical function. The minimum total score was a zero. All nine pictures would have been sorted based on their physical attributes or some other non-functional characteristic to receive a score of zero. A two –way Analysis of Variance was the primary statistical method used to analyze the data.

Procedure

The first step in the data collection for this study was to obtain permission from all necessary parties to carry out the study. First, permission was requested and secured from the school's administration. Secondly, a consent form was sent home with students to gain permission from the students and their parents or guardians for involvement in the study (see appendix B).

On the first day of the study, students took part in the pretest. Once they finished the two sorting exercises, the materials were collected and scored by the researcher.

On the second, third, and fourth days of the study, those students assigned to one of the two treatment groups began the treatment. Students worked individually on each activity. On each day of the study, students engaged in an activity that covered gears, belts and pulleys, or levers. Students received the same materials, regardless of the form of treatment (i.e. convergent or divergent).

On the day they were scheduled to study gears, students were given a mechanism board, a small, medium and large cranking gear as well as a small, medium and large lifting gear and a weight with clip (see appendix J). The gears were arranged on an axle to allow for easy insertion and removal from the mechanism board. The cranking gears were equipped with a handle at the front so that they could be easily turned and the number of turns could be easily recorded. The lifting gears had a pulley attached to the front with a string tied and attached around that pulley to clip on the weight; the gears had a mark on them for ease of recording the number of turns. All gears, regardless of size, meshed together.

When the students studied belts and pulleys they were furnished with a mechanism board, a belt, a weight with clip, and small, medium and large cranking and lifting pulleys (see appendix K). The pulleys were arranged on axles similar to the gears to facilitate easy insertion and removal from the mechanism board. The length of the belt allowed for any combination of pulleys. The cranking pulley included a handle on front, similar to the gear. Also, the lifting pulleys were arranged with two pulleys on the axle, one for the belt and one with a string tied to it for lifting the weight. A mark was also present on the lifting pulley for record the number of turns.

When studying levers, students were given a lever board, a lever with 15 holes in it, a spring scale that measures mass in Newtons, and a 4 Newton weight with an S hook (see appendix L). The lever board was arranged with a bolt sticking out of the center to act as the fulcrum for the levers. The board also included measurement scales on both sides to aid in the gathering of input and output distance data. The lever had two larger holes on each end for the spring scale and weight to be inserted. There were 13 color-coded holes in between the two large holes. These holes allow the lever to be placed onto the bolt and gave students an opportunity to move the fulcrum of the lever. Following each day of treatment, the packets were collected and analyzed by the researcher (see appendix O and P).

At the end of each of the three lab experiences, all students were given a posttest. The posttest was administered using he same materials and techniques as the pretest. Following the second sort, the materials were collected and analyzed by the researcher.

Limitation

A limitation of the methodology used is that the researcher designed the pretest and posttest instrument. Therefore, the reliability and validation of the instrument was not established.

Summary

In conclusion, permission was secured from all necessary parties. Then, the research began with the subjects taking a pretest. Two thirds of the participants received treatment in the form of three convergent or divergent activities. The remaining third received no treatment. Students were then given a posttest and the significance of the results was analyzed through ANOVA procedures.

Chapter IV: Results

Today's technology education is the product of an experiment, which has continuously evolved over time (International Technology Education Association, 2000). From the early days of manual training to industrial arts and now technology and engineering, as the names and foci of the field changed, the techniques used for instructing students have changed as well. Currently, there are two primary ways technology education professionals teach students, using convergent or divergent instruction. Convergent instruction is the most common type of instruction used in today's classrooms. Convergent instruction involves a very explicit progression of instruction, learning is teacher determined and ends with a specified correct solution. Divergent instruction is learner driven, non-linear, and does not necessarily result in only one absolute solution. Convergent instruction has been used for years in the form of lecture, worksheets, and structured laboratory activities. Divergent instruction is finding favor among current technology education professionals as they teach engineering and design taking the form of problem solving and design activities. The aim of this study is to determine which technique best helps students understand mechanisms.

The study took place at Kennedy Middle School in Germantown, Wisconsin and involved 130 eighth grade students enrolled in technology education courses. Students were first given a pre-test. The pre-test involved sorting pictures of mechanisms. Participants were given an envelope containing nine pictures of gears, levers, belts and pulleys arranged as balanced mechanisms, force multipliers, and distance multipliers. Participants were asked to sort the pictures into three groups based on some common characteristic shared by all pictures in that group. The participants then paper clipped the piles together, wrote a modest explanation for the sort on a note card, put all contents into the envelope and handed it in to the researcher. Students were then given the exact same materials a second time and asked to repeat the process. At that point, students were required to use a different defining characteristic to make the groupings. The pretests were then scored according to the category used for the sort. Students who choose to group the pictures based on their physical attributes were considered to have applied superficial thinking, while those who chose to sort the pictures based on their functional characteristics were considered to have applied more sophisticated thinking. Following the pre-test, all students in the researcher's classes received treatment. Some participants received convergent treatment in the form of structured laboratory activities involving mechanisms, while other participants received divergent treatment in the form of an open ended problem solving activity involving mechanisms. Students receiving treatment were assigned to a treatment group based on their sixth grade reading score in an attempt to make the groups as analogous as possible. Students enrolled in three of the researcher's colleagues classes served as the control group and received no treatment. After the treatment groups had completed their activities, all of the participants took the posttest. The posttest was administered and scored in the same manner as the pretest. Pretest to posttest scores were analyzed in an attempt to determine if one instructional technique was better at helping middle school students understand mechanisms.

Background

After all consent forms were collected and student absences were acknowledged, 125 students remained eligible to participate in the study. Table 1 shows demographic breakdown of the participants by gender.

Table 1

Gender of Participants

Gender	Frequency	%
Male	98	78.4
Female	27	21.6

There were a total of 125 participants, and there were considerably more males involved in the study. The gender percentages closely matched the total population of eighth grade students taking technology education classes at Kennedy Middle School.

Participants were divided up into three groups, convergent treatment, divergent treatment and control. Table 2 demonstrates the distribution of students within these groupings. Table 2 also draws attention to the distribution of these groups by gender.

Table 2

Group Distribution

	Male		Female		Total	
Group	Frequency	%	Frequency	%	Frequency	%
Convergent Treatment	34	81	8	19	42	100
Divergent Treatment	33	84.6	6	15.4	39	100
Control	31	70.5	13	29.5	44	100

The number of students in each group was fairly evenly distributed. The control group had the largest number of females.

During the study, students were enrolled in different courses within the technology education department (for more information about Kennedy Middle School schedule see appendix A). Table 3 illustrates which classes students were enrolled in during the study, as well as the day (gold or blue), class time, and the instructor for the course. First hour was from 7:58 – 8:42 AM and second hour was from 8:45-9:29 AM (see Table 22 for more about time of day and performance).

Table 3

Class Distribution by Period, Day and Instructor

Class	Frequency	%	Class Period	Instructor
		Gold Day		
Communication A	13	10.4	2nd Hour	Colleague
Construction B	22	17.6	1st Hour	Researcher
Multimedia	15	12	1st Hour	Colleague
Transportation A	19	15.2	2nd Hour	Researcher
		Blue Day		
Transportation B	16	12.8	1st Hour	Colleague
Enterprise	21	16.8	1st Hour	Researcher
Construction B	19	15.2	2nd Hour	Researcher

The number of students was fairly evenly distributed throughout the seven classes. The original intention was to use only two of the researcher's colleagues classes. However, because students were enrolled in multiple technology education classes, three of the classes instructed by a colleague were used to create three relatively even groups. Those students enrolled in two or more of the classes only partook in the study during one of those classes, and they were given an alternative activity during the other class.

Students enrolled in the researcher's classes received treatment. To make the groups as analogous as possible, students were assigned to treatment groups based on their sixth grade Wisconsin Knowledge and Concepts Examination reading scores. Table 4 demonstrates the breakdown of the reading scores by group.

Table 4

Reading Scores by Grouping

Group	*M*	*SD*	*Mdn*	Range	No Score
Convergent Treatment	670.7	31.06	675	716 - 581	8
Divergent Treatment	675.6	27.3	679	716 - 597	6
Control	673.6	29.5	675	724 - 603	3

Table 4 shows the reading scores across all three groups were very similar. All of the average scores were within 5 points of each other, and each group had similar standard deviations, suggesting that the distribution of scores were reasonably analogous between the groups. Furthermore, the range of scores were relatively close and the median scores were within a few points of each other. Table 3 also shows that 17 students did not have recorded sixth grade reading scores. Students without reading scores were randomly assigned to treatment groups. Originally, the divergent treatment group included one more student without a recorded reading score; however, due to absences, that student was unable to participate in the study.

Each of the topics had an associated laboratory activity, and each laboratory activity consisted of three parts. These three parts were aimed to help students understand the theoretical attributes of mechanisms. Each student's laboratory activity packet was scored to determine if they completed each of the three parts (see appendixes O and P for score sheet). A student completing all three sections received a score of three. Incomplete sections received a score of zero. Table 5 shows the completion scores broken down by treatment group and gender.

Table 5

Rate of Laboratory Activity Completion by Treatment Group and Gender

	Convergent Treatment Group			Divergent Treatment Group			Total		
Average	Male (n = 34)	Female (n = 8)	Total (n = 38)	Male (n = 32)	Female (n = 6)	Total (n = 42)	Male (n = 66)	Female (n = 14)	Total (n = 80)
				Gear Lab Activity Completion					
M	2.97	3.00	2.98	2.63	2.50	2.61	2.80	2.79	2.80
SD	.171	.000	.154	.942	1.225	.974	.684	.802	.701
				Belt Lab Activity Completion					
M	2.94	3.00	2.95	2.63	3.00	2.68	2.79	3.00	2.83
SD	.343	.000	.309	.751	.000	.702	.595	.000	.546
				Lever Lab Activity Completion					
M	3.00	2.75	2.95	2.53	2.67	2.55	2.77	2.71	2.76
SD	.000	.463	.216	.879	.816	.860	.652	.611	.641

Table 5 demonstrates that most students completed their activities. The convergent treatment group had a higher rate of completion than the divergent group. Also, the standard deviations on the convergent group's scores were much lower than the standard deviations on the divergent group's scores, which shows that the convergent group was more consistent in their activity completion. Within the convergent treatment group, all females fully completed the belt and pulley activity as well as the gear activity, while all of the males fully completed the lever activity. As a whole, the differences in completion rates between males and females were not large. Since the number of females studied is smaller than the number of males, the number of participants limits any conclusions related to gender. Finally, it is noted that completion rates between activities was very consistent. That is, one activity does not appear to have been favored over another.

A two-way analysis of variance (ANOVA) was used to analyze if treatment group assignment or gender had a significant effect on the completion rate of each laboratory activity. Tables 6 through 8 display the findings.

Table 6

Effect of Treatment Group and Gender on the Gear Activity Completion Rate

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	2.758	1	2.758	5.828	.018*
Gender	.017	1	.017	.036	.851
Treatment Group Assignment & Gender	.068	1	.068	.143	.706
Residual	35.971	76	.473		
Total	38.800	79	.491		

*$p < .05$.

Table 6 shows that treatment group assignment had a significant effect on the gear activity completion rate at the .05 level. Gender did not have a significant effect on gear activity completion rate nor was there an interaction effect between gender and treatment.

Table 7

Effect of Treatment Group Assignment and Gender on the Belt and Pulley Activity Completion Rate

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	1.364	1	1.364	4.849	.031*
Gender	.449	1	.449	1.597	.210
Treatment Group Assignment & Gender	.284	1	.284	1.008	.318
Residual	21.382	76	.281		
Total	23.550	79	.298		

*$p < .05$.

Table 7 shows that treatment group assignment had a significant effect on the belt and pulley completion rate at the .05 level. Gender did not have a significant effect on belt and pulley activity completion rate nor was there an interaction effect based on treatment group assignment and gender.

Table 8

Effect of Treatment Group Assignment and Gender on the Lever Activity Completion Rate

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	3.225	1	3.224	8.508	.005**
Gender	.076	1	.076	.200	.656
Treatment Group Assignment & Gender	.422	1	.422	1.113	.295
Residual	28.02	76	.379		
Total	32.488	79	.411		

$^{**}p < .01$.

Tables 8 shows that treatment group assignment had a significant effect on lever activity completion rate at the .01 level. Gender did not have a significant effect on gear activity completion rate nor was there an interaction effect based on treatment group assignment and gender.

From Tables 6 through 8, we can infer the completion rate of all laboratory activities was significantly affected by treatment group assignment, while gender and the interaction of gender and treatment group assignment did not have a significant effect on completion rates.

In each laboratory activity, students were asked culminating questions to help gauge their understanding. Each activity consisted of three sets of three culminating questions. The activity packets were scored to determine if the students correctly answered these questions. Each question was worth one point. A correct response was awarded one point, and incorrect response received a score of zero. Each laboratory activity packet had a potential score of nine points. Table 9 shows the culminating question scores by treatment group and gender.

Table 9

Culminating Questions Scores by Treatment Group and Gender

	Convergent Treatment Group			Divergent Treatment Group			Total		
Average	Male (n = 34)	Female (n = 8)	Total (n = 38)	Male (n =32)	Female (n = 6)	Total (n = 42)	Male (n = 66)	Female (n = 14)	Total (n = 80)
				Gear Lab					
M	5.15	4.50	5.02	2.25	2.83	2.34	3.74	3.79	3.75
SD	2.26	1.151	2.14	1.918	1.72	1.88	2.54	1.76	2.416
				Belt and Pulley Lab					
M	4.97	4.13	4.81	1.88	3.50	2.13	3.47	3.86	3.54
SD	2.17	1.96	2.13	1.88	1.38	1.89	2.55	1.70	2.42
				Lever Lab					
M	5.50	3.38	5.10	2.34	1.83	2.26	3.97	2.71	3.75
SD	2.06	1.41	2.12	2.54	1.60	2.40	2.78	1.64	2.66

Table 9 clearly displays differences between student performances on the culminating questions asked at the end of the activities. As a whole, the convergent treatment group performed better than the divergent treatment group. These results may suggest that students who participated in convergent treatment activities better understood mechanisms. Within the convergent treatment group, the males answered more culminating questions correctly than the females. Within the divergent treatment group the females performed better on two out of three activities. Again the number of females was much lower than the number of males, which may have affected the results. It does not appear that any one activity resulted in substantially higher or lower culminating scores than any others. It is noteworthy to mention that the students in the divergent treatment group were asked short-answer questions while the convergent treatment group was asked multiple-choice questions. Thus, differences in the question format may have affected the findings.

A two-way analysis of variance was used to consider the effect that treatment group assignment and gender had on students culminating question scores. Tables 10 through 12 display the results.

Table 10

Effect of Treatment Group Assignment and Gender on the Culminating Question Scores of the Gear Laboratory Activity

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	143.584	1	143.584	34.853	.000**
Gender	.134	1	.134	.033	.857
Treatment Group Assignment & Gender	4.297	1	4.297	1.043	.310
Residual	313.098	76	4.120		
Total	461.000	79	5.835		

$^{**}p < .01$.

Table 10 shows that treatment group assignment had a significant effect on students culminating question scores during the gear laboratory activity at the .01 level. Gender and the interaction of gender and treatment group assignment did not significantly affect the gear activity culminating question scores.

Table 11

Effect of Treatment Group Assignment and Gender on the Culminating Question Scores of the Belt and Pulley Laboratory Activity

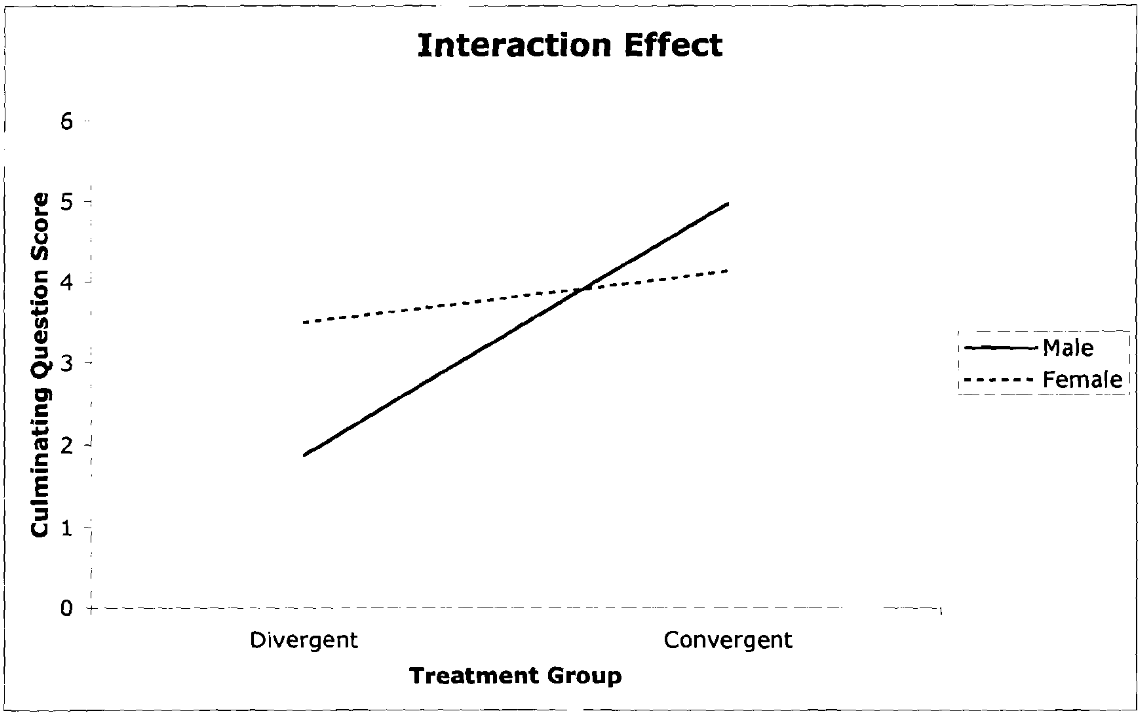
Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	141.984	1	141.984	35.868	.000**
Gender	.649	1	.649	.164	.687
Treatment Group Assignment & Gender	17.324	1	17.324	4.376	.040*
Residual	300.846	76	3.958		
Total	461.888	79	5.847		

$^{*}p < .05$. $^{**}p < .01$.

Table 11 shows that treatment group assignment had a significant effect on belt and pulley laboratory activity culminating question scores at the .01 level. Table 13 also shows that the interaction of treatment group and gender had a significant effect on these scores at the .05 level. Gender alone, did not have a significant effect on the belt and pulley laboratory culminating question scores. The means of each group were plotted to determine the type of interaction. Figure 1 shows the results.

Figure 1

Analysis of Interaction Effect on the Belt and Pulley Activity Culminating Question Scores.



The interaction effect was found to be disordinal. This was primarily caused by the large differences in the male convergent and divergent treatment group scores.

Table 12

Effect of Treatment Group Assignment and Gender on the Culminating Question Scores of the Lever Laboratory Activity

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	164.970	1	164.970	34.216	.000**
Gender	23.161	1	23.161	4.804	.031*
Treatment Group Assignment & Gender	7.399	1	7.399	1.535	.219
Residual	366.427	76	4.821		
Total	557.000	79	7.051		

$*p < .05$. $**p < .01$.

Table 12 shows that treatment group assignment had a significant effect on lever laboratory activity culminating question scores at the .01 level. Gender also had a significant effect on these scores at the .05 level. The interaction of treatment group assignment and gender did not have a significant effect on the laboratory activity culminating question scores.

Tables 10 through 12 show that treatment group assignment had a significant effect on culminating question scores for all three laboratory activities at the .01 level. It was also observed that during the belt and pulley laboratory activity, the interaction between treatment group assignment and gender had a significant effect on the culminating question scores. Furthermore, the results demonstrate gender had a significant effect on the lever activity scores.

Treatment

Table 13 shows the average trial one and two pretest and trial one and two posttest scores of all participants in the study. The scores are broken down by assigned treatment group and gender.

Table 13 –

Average Pretest and Posttest Scores by Treatment Group and Gender

	Trial #1 Pretest		Trial #2 Pretest		Trial #1 Posttest		Trial #2 Posttest	
Gender	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Convergent Treatment Group								
Male (n = 34)	.00	.00	2.76	3.066	.94	2.348	3.00	3.393
Female (n = 8)	.00	.00	3.75	3.151	1.75	2.659	2.88	3.482
Total (n = 42)	.00	.00	2.95	3.068	1.10	2.397	2.98	3.368
Divergent Treatment Group								
Male (n = 33)	.00	.00	3.52	3.346	.97	2.675	3.39	3.142
Female (n = 6)	.00	.00	1.33	1.633	1.17	2.858	.33	.816
Total (n = 39)	.00	.00	3.18	3.227	1.00	2.666	2.92	3.107
Control Group								
Male (n = 31)	.00	.00	2.10	2.856	.48	1.288	2.58	2.566
Female (n = 13)	.00	.00	4.31	2.359	2.08	2.597	2.15	3.132
Total (n = 44)	.00	.00	2.75	2.878	.95	1.892	2.45	2.715
Total								
Male (n = 98)	.00	.00	2.81	3.122	.81	2.190	3.00	3.053
Female n = 27)	.00	.00	3.48	2.680	1.78	2.592	1.96	2.968
Total (n = 125)	.00	.00	2.95	3.034	1.02	2.307	2.78	3.053

Table 13 shows that in many cases, student scores declined between the pretest and posttest instrument. An exception to this was the convergent treatment group males and the control group males, whose scores improved over time. Overall, the males had a slight increase between trial two pretest and trial two posttest, while the females had a noticeable decline between the pretest and posttest. However, these may not be fair measures because all groups displayed a score above zero in both posttest trials, something that cannot be said for both pretest trials.

Table 14 compares the averages of trials one and two pretest and trials one and two posttest. It also displays the increase by percentages.

Table 14

Pretest and Posttest Average Scores and Percentage Increase

Gender	Pretest	Posttest	% Increase
	Convergent Treatment Group		
Male (n = 34)	1.38	1.97	6.6
Female (n = 8)	1.875	2.315	4.9
Total (n = 42)	1.475	2.04	6.3
	Divergent Treatment Group		
Male (n = 33)	1.76	2.18	4.7
Female (n = 6)	.0665	.75	.9
Total (n = 39)	1.59	1.96	4.1
	Control Group		
Male (n = 31)	1.05	1.53	5.3
Female (n = 13)	2.155	2.115	-.4
Total (n = 44)	1.375	1.7	3.6
	Total		
Male (n = 98)	1.405	1.905	5.6
Female (n = 27)	1.74	1.87	1.4
Total (n = 125)	1.475	1.9	4.7

Table 14 shows an increase in scores between the pretest and posttest, although the increase was quite small. The convergent group showed the greatest increase and the control group showed the least. Males showed a greater increase than females.

A two-way analysis of variance was used to analyze the significance of treatment group assignment and gender on student scores during the pretest and posttest. Because all students scored a zero on pretest trial one, an analysis of variance could not be used. Tables 15 through 17 show the findings.

Table 15

Effect of Treatment Group Assignment and Gender on Student Pretest Trial Two Scores

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	5.839	2	2.920	.327	.722
Gender	11.680	1	11.680	1.308	.255
Treatment Group Assignment & Gender	63.546	2	31.773	3.558	.032*
Residual	1062.672	119	8.930		
Total	1141.712	124	9.207		

*$p < .05$.

Table 15 shows that the score earned by students on pretest trial two was significantly affected by the interaction between gender and treatment group assignment at the .05 level. As single effects of gender and treatment group assignment did not influence student performance during pretest trial two.

The means of each group were plotted determine the type of interaction effect. Figure 2 displays the results.

Figure 2:

Analysis of Interaction Effect on Pretest Trial Two Scores

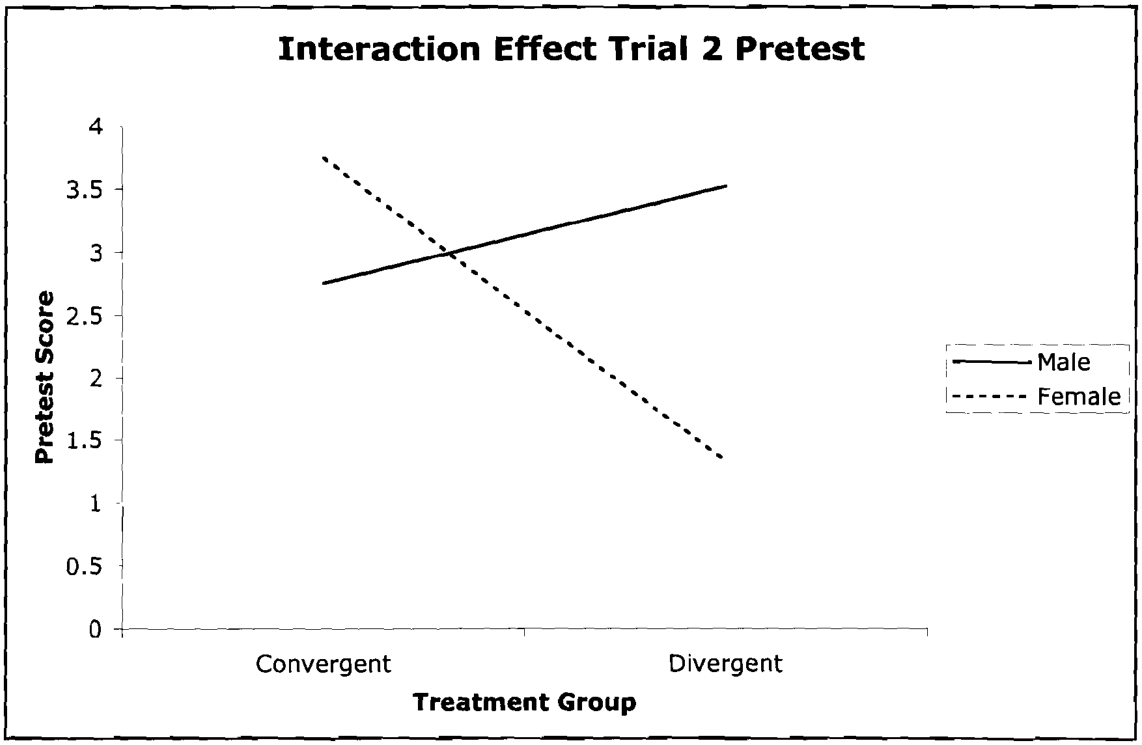


Figure 2 demonstrates that the interaction effect of treatment group assignment and gender during pretest trial two was disordinal. The effect was caused mainly by the large differences in pretest trial two scores between the convergent group females and the divergent group females.

Table 16

Effect of Treatment Group Assignment and Gender on Student Posttest Trial One Scores

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	1.401	2	.701	.132	.877
Gender	20.946	1	20.946	3.945	.049*
Treatment Group Assignment & Gender	6.731	2	3.366	.634	.532
Residual	631.850	119	5.310		
Total	659.968	124	5.322		

*$p < .05$.

Table 16 shows student scores on posttest trial one were significantly affected by gender at the .05 level. Student scores were not significantly affected by treatment group assignment or the interaction between treatment group and gender.

Table 17

Effect of Treatment Group Assignment and Gender on Student Posttest Trial Two Scores

Source	*SS*	*df*	*MS*	*F*	Sig.
Treatment Group Assignment	4.120	2	2.060	.223	.800
Gender	19.812	1	19.812	2.145	.146
Treatment Group Assignment & Gender	29.515	2	14.757	1.597	.207
Residual	1099.328	119	9.238		
Total	1155.782	124	9.320		

Table 17 shows that gender, treatment group assignment and the interaction between the two, did not affect students' scores on posttest trial two.

Tables 15 through 17 clearly demonstrate that treatment group assignment had no significant effect on pretest or posttest scores. During posttest trial one, gender had a significant effect on student performance. Also, during pretest trial two, the interaction of gender and treatment group assignment had a significant effect on the scores.

Order of Presentation

Students in the treatment groups were given three different laboratory activities. One activity dealt with gears, one with levers, and another with belts and pulleys. Because of the number of manipulatives available, not all students experienced the same activity on the same day. Some students started with gears on day one, others with levers and some with belts and pulleys. On the second and third days, students experienced the remaining two. Table 18 displays the order in which the students were given these three activities.

Table 18

Order of Laboratory Activities

Group	Order of Activities					
	G – B - L		L – G – B		B - L - G	
	Frequency	%	Frequency	%	Frequency	%
Convergent Treatment	15	35.7	16	38.1	11	26.2
Divergent Treatment	11	28.2	12	30.8	16	41.0
Total	26	32.1	28	34.6	27	33.3

Note. B = belt and pulley activity; L = lever activity; G = gear activity

As indicated by the table above, the order in which the activities were presented was evenly distributed.

Table 19 presents the average scores on the pretest and posttest broken down by the order in which the laboratory activities were presented. For the pretest and posttest there was a possible score of nine. Pretest trial number one was omitted because all students received a score of zero on the initial sorting activity.

Table 19

Average pretest/posttest scores broken down by laboratory activity presentation order

Presentation Order	N	*M*	*SD*
	Trial #2 Pretest		
G – B – L	26	3.31	2.990
L – G – B	28	3.29	3.387
B – L – G	27	2.59	3.041
Total	81	3.06	3.128
	Trial #1 Posttest		
G – B – L	26	1.31	2.825
L – G – B	28	1.18	2.709
B – L – G	27	.67	1.981
Total	81	1.05	2.514
	Trial #2 Posttest		
G – B – L	26	2.85	3.563
L – G – B	28	3.46	3.283
B – L – G	27	2.52	2.847
Total	81	2.95	3.225

Note. B = belt and pulley activity; L = lever activity; G = gear activity

Table 19 shows that the group receiving the gear activity first and the group receiving the lever activity initially outpaced the group receiving the belt and pulley activity. Large standard deviations are noticed, which suggests a wide range of scores within each group.

Table 20 illustrates the average completion rates on the laboratory activities and the average culminating question scores based on order of laboratory activity presentation. The completion rate had a possible score of three, and the culminating question score had nine points possible.

Table 20

Average Laboratory Activity Completion Rates and Culmination Question Scores by Laboratory Activity Presentation Order

Presentation Order	N	*M*	*SD*
	Gear Activity Completion Rate		
G – B – L	25	3.00	.00
L – G – B	28	2.54	.999
B – L – G	27	2.89	.577
Total	80	2.80	.701
	Belt & Pulley Activity Completion Rate		
G – B – L	25	2.92	.400
L – G – B	28	2.64	.780
B – L – G	27	2.93	.267
Total	80	2.83	.546
	Lever Activity Completion Rate		
G – B – L	25	2.92	.400
L – G – B	28	2.71	.659
B – L – G	27	2.67	.784
Total	80	2.76	.641
	Gear Culminating Question Score		
G – B – L	25	4.96	1.814
L – G – B	28	3.39	2.558
B – L – G	27	3.00	2.402
Total	80	3.75	2.416
	Belt & Pulley Culminating Question Score		
G – B – L	25	4.60	2.160
L – G – B	28	3.57	2.588
B – L – G	27	2.52	2.082
Total	80	3.54	2.418
	Lever Culminating Question Score		
G – B – L	25	5.12	2.205
L – G – B	28	3.36	2.670
B – L – G	27	2.89	2.607
Total	80	3.75	2.655

Note. B = belt and pulley activity; L = lever activity; G = gear activity

Table 20 shows little if any noticeable trends between order of laboratory activity presentation and completion rates and culminating question scores. It appears the group receiving the gear activity first was the highest scoring group in most cases. The groups' culminating question scores and completion rates remained fairly constant throughout the three activities. For instance, the group starting with the lever laboratory activity had an average completion rate of 2.71 and an average culminating question score of 3.36 on their first activity, 2.54 and 3.39 respectively on their second activity, and 2.64 and 3.57 respectively on their third activity. These results indicate very little variation between their scores on the three activities.

Table 21 shows the results of a one-way analysis of variance was used to determine if the order in which students experienced the laboratory activities had any significant effect on their pretest/posttest performance, their activity completion rate, and the culminating question scores. Because all students received a score of zero on pretest trial one, ANOVA was not possible and therefore is not included in the table below.

Table 21

Effect of Presentation Order on Pretest/Posttest Scores, Activity Completion Rates, and Culminating Question Scores

Source	*SS*	*df*	*MS*	*F*	Sig.
	Trial #2 Pretest				
Between Groups	8.920	2	4.460	.450	.640
Within Groups	773.771	78	9.920		
Total	782.691	80			
	Trial #1 Posttest				
Between Groups	6.157	2	3.078	.481	.620
Within Groups	499.646	78	6.406		
Total	505.802	80			
	Trial #2 Pretest				
Between Groups	12.713	2	6.356	.605	.548
Within Groups	819.090	78	10.501		
Total	831.802	80			
	Gear Activity Completion				
Between Groups	3.169	2	1.585	3.424	.038*
Within Groups	35.631	77	.287		
Total	38.800	79			
	Belt & Pulley Activity Completion				
Between Groups	1.430	2	.715	2.488	.090
Within Groups	22.120	77	.287		
Total	23.550	79			
	Lever Activity Completion				
Between Groups	.933	2	.467	1.139	.326
Within Groups	31.554	77	.287		
Total	23.550	79			
	Gear Activity Culminating Question Score				
Between Groups	55.361	2	27.681	5.254	.007**
Within Groups	405.639	77	5.268		
Total	461.000	79			
	Belt & Pulley Culminating Question Score				
Between Groups	56.290	2	28.145	5.343	.007**
Within Groups	405.598	77	5.268		
Total	461.888	79			
	Lever Activity Culminating Question Score				
Between Groups	71.265	2	35.632	5.649	.005**
Within Groups	485.735	77	6.308		
Total	557.000	79			

*$p < .05$. **$p < .01$.

Table 21 shows the order in which students were presented with the three lab activities had a significant effect on their culminating question scores at the .01 level. Table 21 also demonstrates that the order in which students were presented with the lab activities had a significant effect on the number of activities they completed during the gear laboratory activity at the .05 level. The order of presentation did not significantly affect the completion rate on the belts and pulleys or levers laboratory activity; however, the effect of order on the belt and pulley laboratory activity approached significance. Finally, Table 21 shows that the order of laboratory activity presentation had no significant effect on the students' scores during the pretest and posttest sorting activities.

Time of Day

A *t*-test was run to determine if the time of day had any significance on student performance. Table 22 shows the results of this test. Pretest trial one was omitted because all students received a score of zero, thus making a *t*-test impossible.

Table 22

Significance of Time of Day on Pre/Posttest Scores, Activity Completion Rates, and Culminating Question Scores

Subject	*t*	df	Sig. (2-tailed)
Pretest Trial 2	-.926	123	.356
Posttest Trial 1	-.486	123	.628
Posttest Trial 2	-.979	123	.330
Gear Activity Completion Rate	-.766	78	.446
Belt & Pulley Activity Completion Rate	-.194	78	.847
Lever Activity Completion Rate	-.274	78	.785
Gear Activity Culminating Question Score	-.671	78	.504
Belt & Pulley Activity Culminating Question Score	-.379	78	.705
Lever Activity Culminating Question Score	-.375	78	.722

As demonstrated in Table 22, time of day had no significance on student performance.

Chapter V: Discussion, Conclusions, and Recommendations

Today's technology education is the product of an experiment, which has continuously evolved over time. From the early days of manual training to industrial arts to technology and engineering as the names and foci of the field changed the techniques used for instructing students have also evolved. Two of the instructional methods technology education professionals can use to teach their students include convergent and divergent instruction. Convergent instruction is the most common type of instruction used in traditional classrooms. Convergent instruction prescribes a very explicit progression of learning, which is teacher determined and ends with one and only one correct solution. Divergent instruction is learner determined and non-linear. Divergent instruction does not lead to only one absolute solution. Convergent instruction has been used for years in the form of lecture, worksheets, and structured laboratory activities. Divergent instruction is finding favor among technology education professionals who teach engineering and design through problem solving and design activities. The aim of this study was to determine which instructional methodology would have the greatest effect on students' sophistication of thinking regarding mechanisms.

Research Questions

This study attempted to answer the following questions:

1. What effect does the completion of a convergent lab activity have on students' sophistication of thinking regarding mechanisms?

2. What effect does the completion of a divergent lab activity have on students' sophistication of thinking regarding mechanisms?

3. What is the difference in students' sophistication of thinking regarding mechanisms relative to their completion of a convergent lab activity versus completion of a divergent lab activity?

4. What effect does gender have on students' sophistication of thinking regarding mechanisms?

Research Design

The study was a quasi-experimental design, using non-equivalent groups of middle school students, with two treatments and a control. The dependent variable in this study was the type of thinking students applied to the sorting of mechanisms. As defined by the researcher, students who sorted the pictures of mechanisms based on physical attributes or some other characteristic showed superficial thinking while those students who sorted the pictures based on theoretical function showed sophisticated thinking. The independent variable was the type of treatment they received. The effect of gender was also investigated

Discussion

Convergent Treatment Findings

Results indicated the treatment group assignment was a significant factor for all three of the laboratory activities. It was found that convergent treatment students completed their activities and answered their culminating questions at a higher rate than the divergent treatment group. These findings are not surprising, as middle school students are often familiar with following a teacher-prescribed route to knowledge acquisition, which was the main characteristic of the convergent treatment. Students receiving convergent treatment performed better on the posttest than the pretest; however, the increase was only about 3% greater than the control group. As such, it was found that treatment group assignment did not have a significant effect on posttest results.

Divergent Treatment Findings

Students involved in the divergent treatment group performed better on the posttest than the pretest. However, the increase was small and not statistically significant as the students performed only 0.5% better than the control group. Regardless, what is of most interest was the divergent treatment group's observed performance during the treatment portion of the study. Students in the divergent treatment group were more likely to give up, hurry through, or become stuck and run out of time. These observations were confirmed by the results, as the divergent treatment group completion rates were lower than the convergent group. Furthermore, students who received the divergent, open-ended activity, often appeared confused, found the activities difficult, and seemed unable to construct meaning from their experience. These findings support the behavioral observations, as students in the divergent treatment group had lower culminating question scores. It is noteworthy to mention that the divergent activities required students to answer open-ended short answer culminating questions, while the convergent treatment group answered multiple-choice questions. Thus the questioning format may have had an influence on the findings by treatment group.

Gender Findings

Within the divergent treatment group, the females outperformed the males on culminating question scores. Further, on the belt and pulley activity, gender significantly affected these scores. Overall female scores on the pretest and posttest were lower than those of the males.

Effects of Treatment Over Time

Students in both treatment groups increased their scores between the pretest and posttest. The increase was, however, quite modest. The convergent group made a 2.5% gain over the divergent group, but considering the differences in completion rates and culminating question scores, these results were expected. Additionally, there was no significant effect between group assignment and posttest scores. The differences in the performance of the two groups during the treatment portion of the study was remarkable. The students in the convergent group completed their activities and correctly answered their culminating questions more frequently than the divergent group. The result may have been due to the comfort level of the students, as they are more familiar with convergent activities and the structure they bring. It also shows that divergent instruction, as in design, requires some background knowledge. Thus the developmental level of the middle school students and their corresponding lack of foundational knowledge in the area of mechanisms likely points to the need of explicit instruction or convergent methodologies.

Order of Presentation

The order in which students received treatment was considered to determine if order had an effect on the outcomes. The groups receiving the gear activity first did the best on the posttest, had better completion rates, and culminating question scores. The order of presentation had a significant effect on culminating questions scores during all three activities, and it also had a significant effect on the completion rate during the gear activity. The significance of presentation order on the posttest scores is worth noting. However, the difference may have less to do with the order of presentation and more to do with the students who were presented the activities in that order. It was found that the students receiving the gear activity first had an average sixth grade reading score of 689, the students receiving the belt and pulley activity first had an average score of 668, and the group receiving the lever activity first had an average score of 652, however their group had 14 missing reading scores. Although these differences appear slight, the groups' respective reading averages may shed some light as to why the group who received the gear activity first did so well.

Vocabulary

Exposure to the treatment activities helped students to increase their vocabulary relative to the names of mechanisms. During the pretest trials, student note cards included the word lever 17 times, the words belt and/or pulley 62 times, and the word gear 74 times to describe the pictures used during the sorting activity. Students typically used phrases like "rod thingy", "spiky wheels", or "round wheels connected by a tube or something" to describe the mechanisms. Following the treatment and during trials one and two of the posttest, the students' note cards included the word lever 54 times, belt and or pulley 81 times, and gear 84 times. Thus, these results represent a considerable increase in the appropriate use of terminology to describe mechanisms. While learning vocabulary was not a main focus of the laboratory activities, these results are important, and may help students in the future as they interact with mechanisms and strive for technological literacy.

Conclusions

Based on the findings of this study the following conclusions can be made:

1. Middle School students perform well when activities are structured. Students are familiar with structure and explicit instruction within the school setting. The convergent treatment offered that structure. The instructor was not physically present at each step, but by creating a thorough activity packet, the instructor provided the student with a structured path. The result was that students completed the activities and correctly answered questions more often.

2. Without structure of any type, middle school students will likely struggle. The divergent activity offered only a problem without a path to follow. The instructor had not previously instructed the students regarding mechanisms and was not available to help guide them toward understanding as they proceeded through the activity. Thus, the students were completely on their own. As a result middle school students were less likely to complete their activities and move likely to answer questions incorrectly when divergent instruction was implemented.

3. Proper divergent instruction requires convergent instruction. Both treatments resulted in some learning, however the formative measures used to monitor the path to final understanding demonstrated that convergent instruction produced better results for middle school students. Design, the technique used to represent divergent instruction during this study, is a synthesis level activity. However complex, design relies on accessing lower level information (Agogino, Dym, Eris, Frey, and Leifer, 2005), and factual lower level knowledge can be efficiently gained through convergent instruction. Design is appropriate as a capstone type of activity. After students have been given requisite knowledge they need to construct a solution. Without the lower levels of

knowledge students have no means by which to determine a starting point or evaluate their designs.

4. Convergent instruction alone does not ensure mastery. Convergent instruction may give students familiarity with a concept, but not a deep understanding of it. Divergent instruction can be used to help students take lower level concepts and connect them together to create a superior final solution. It is this piecing of parts together (i.e. scaffolding knowledge) that leads to the development of deep understanding or mastery. If convergent instruction alone resulted in mastery, one would have expected students to significantly outperform the divergent group. As the findings demonstrated, the convergent group did not outperform the divergent group during the posttest period.

5. Females are likely to respond differently than the males in the middle school technology education classrooms. In this study, females performed better on the divergent activity culminating questions, which were in short answer format. These results suggest females may have an easier time answering short answer questions than males. Historically, technology education topics have centered on male interests, thereby reducing the involvement of females in technology education (Wisconsin Department of Public Instruction, n.d.) The historical lack of attention to the learning needs of females in technology education classrooms may have been part of the reason females demonstrated less of an increase in learning between the pretest and posttest. It is possible that females were less comfortable making inferences or judgments about sorting mechanisms due to their lack of familiarity.

Recommendations

For teachers

Both types of instruction require the instructor to be properly prepared; the difference is when that preparation is offered. During divergent instruction, the teacher must be an active coach. Teachers must be able to gently nudge students when they become confused while offering a bit of structure to the learning process. Convergent instruction requires preparation and effort on the front end. Either the teacher is built into the instructional packet and the activity can survive autonomously or the teacher is actively disseminating knowledge to the class. Using either technique, there is no shortcut; teachers must be prepared regardless of the type of instruction used.

Design cannot be used as a stand-alone activity. Middle School students are first beginning to be able to maturely deal with abstraction (Hergenhahn & Olson, 1997). Giving middle school students a design activity without first providing introductory knowledge or structure may result in failure. It is irresponsible to think that students will be able to apply higher level thinking when they do not have a solid foundational knowledge. Students cannot use analytical or synthesis skills without first having an appropriate amount of background knowledge (Bar-Yam, Bar-Yam, Kaput, Rhoades, & Sweeney, 2002). Design has great potential to create meaningful learning opportunities, but design must be preceded by explicit instruction.

Convergent instruction is efficient, and has a place in the middle school classroom setting. When ideas and concepts need to be presented to prepare students to apply higher level thinking, convergent instruction is a good choice. As was demonstrated in this study, middle school students are comfortable with the procedures involved and react favorably. There is no shame in using convergent instruction to introduce concepts.

It is important to be sensitive to the differences in the ways males and females learn and behave in the technology education classroom. The instructor should give females various ways to express themselves (Gurian, 2001). It is also important that topics and projects are carefully chosen to avoid intimidating or alienating female students. Teachers must create an environment where females are comfortable and poised to enjoy success.

For further study

To validate these findings, replication is needed. To that end it would be helpful to include either smaller groups, or trained helpers in the classroom to attend to student needs during the activities.

Further investigation into gender's role in sophistication of thinking regarding mechanisms is also recommended. A larger number of female participants would strengthen the study to make the findings more generalizable.

Another study could pair these laboratory activities with formal or direct instruction (i.e. lecture) on mechanisms to study the change in sophistication of thinking over time. Understanding the impact of direct and formal instruction could help teachers make better choices when choosing instructional methodologies.

Investigations involving convergent and divergent methodologies to teach other topics would serve to determine if the findings of this study can be generalized to multiple topics or if they are specific to the study of mechanisms.

Further research on the effects of convergent and divergent instruction involving students in other age groups are needed. Perhaps high school technology students would benefit from divergent instructional methodologies due to their higher levels of abstract reasoning skills.

Summary

The study was designed to determine the effect of convergent and divergent instruction on helping students increase their sophistication of thinking regarding mechanisms. It involved 125 eighth grade students at Kennedy Middle School in Germantown, Wisconsin during the spring of 2007.

The study was a quasi-experiment, using a non-equivalent groups design with two treatments and a control. For the pretest, students were asked to sort nine pictures of mechanisms into groups twice, each time based on a different common attribute. Sophisticated thinking was demonstrated by sorting mechanisms based on their theoretical function, while sorting based on physical attributes showed superficial thinking. Students were divided into three groups, one receiving a convergent treatment in the form of a traditional laboratory activity, one receiving a divergent treatment in the form of a design problem, and a third received no treatment and acted as the control. The activities were designed to teach students about mechanisms. Following the treatment, students received a posttest in the same manner as the pretest.

It was determined that there was no significant effect between treatment group and posttest scores. However, it was found that students experiencing convergent treatment were more likely to finish their activities and correctly answer culminating questions than the divergent treatment group. It was also found that females correctly answered short answer questions more often, but they did worse on the posttest than the males.

The following conclusions were made based on the findings. Divergent instruction cannot stand alone in the middle school setting, as it is a synthesis level activity and requires appropriate requisite knowledge. Convergent instruction is efficient at helping students to gain foundational knowledge and is, in many cases, entirely appropriate. However, convergent instruction alone does not ensure mastery of a subject, as shown in this study. While the convergent group performed better during formative assessments, they did not perform appreciably better on the summative assessments. Females are likely to learn and behave differently in the technology education classroom.

The following recommendations were made for teachers. All instruction requires proper preparation, the type of instruction will dictate when the teacher is most active. Do not expect middle school students to be able to engage in meaningful design activities without first giving them foundational knowledge; and still, even then, they may not be able to construct meaning from design activities. Using convergent instruction is efficient and may help students to build lower level foundational knowledge. It is important to be sensitive to the differences males and females behave and learn.

In order to validate these findings, many replication studies would be needed, but besides replicating this study the following are suggested for further study. Further investigation into gender's role in sophistication of thinking regarding mechanisms would be meaningful. Pairing these laboratory activities with direct or formal instruction would help teachers make decisions regarding instructional methodology. Using divergent and convergent instruction with other topics could help to make these findings more generalizable. Finally, effect of convergent and divergent instruction on students of other age groups would be meaningful.

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Appendix A:

Description of Kennedy Middle School

Kennedy Middle School is located in Germantown, Wisconsin, which is about 20 miles northwest of Milwaukee, Wisconsin. The community of Germantown was once considered rural; however recent growth and scenic landscapes have lead to it becoming an affluent suburban community. Approximately 18,000 people live in Germantown and the community is quite homogenous, with 95% of the population listed as white non-Hispanic (U.S. Census Bureau, 2000); however Kennedy Middle School caters to a larger percentage of minorities as a result of school choice programs (Parrish, 2001). The average yearly family income for the village of Germantown in 1999 was approximately $69,000, with a median home value of $170,000 (U.S. Census Bureau, 2000). The community is well educated, with about 92% of residents over the age of 25 having at least a high school diploma, and approximately 29% having a bachelor's degree or higher. Kennedy Middle School is the only middle school in Germantown, serving approximately 900 students in grades six through eight.

The Kennedy Middle School Technology Education Program is made up of two teachers and is part of the coordinated arts department. Both teachers attended the University of Wisconsin – Stout, with one having six years experience and a master's degree in technology education, and the other having 2 years experience and pursuing a master's degree also in technology education. The coordinated arts department is made up of elective courses and consists of art, Spanish, band, chorus, physical education, sixth grade computer applications, and technology education. The students have six academic periods (i.e. math, social studies, language etc.) and two elective periods each day.

Students in sixth grade have a mandatory quarter long introduction course in each of the coordinated arts subjects. In seventh and eighth grade they are allowed to choose their elective classes. The technology education offerings include classes in the study of communication, transportation, construction, and manufacturing. Communication is designed to help students understand how humans communicate and the importance of clear communication. Activities in communication include creating a telegraph, paper plate speaker, and video. Transportation aims to help students comprehend the role that transportation plays in their lives either actively or passively as well as studying some aspects of vehicle design. Students create a CO_2 car, a boat hull, engage in an intermodal transportation simulation activity, build a rocket and mouse trap car, and design the car of the future. The goal of construction is to give students some insight into the many aspects of constructing structures from planning to implementation. Students in this course will create a balsa wood bridge, a model skyscraper, a miniature wall section, and engage in some simple plumbing and electrical exercises. Finally manufacturing is designed to help students realize the many process and materials that are a part of creating objects they use daily, and it desires to help student learn different career paths within manufacturing. In this course students will make artifacts using both mass production and craftsman techniques, they will learn about materials and their properties through lab experiences, they will engage in a flashlight innovation activity, and take on challenges that help them to learn about various manufacturing careers. Students who sign up for one of the classes in seventh grade will have the A version of the course. In eighth grade, if they choose to continue their study of that content area, they would take the B version of the course. For example, if a child signs up for Construction A in seventh grade, the child would then sign up for Construction B, a differently structured course, in eighth grade. Seventh grade A courses are intended to be prerequisites for B courses in eighth grade, however this rule is not enforced.

The daily schedule at Kennedy Middle School is tailored so that students can have physical education classes weekly throughout the entire school year. The schedule follows a two-day rotation. Coordinated arts classes meet every other day, with the exception of band and chorus which meet daily. Each day is labeled blue or gold. On blue days students would have one pair of coordinated arts classes and on gold days an entirely different pair. With this arrangement students will have their technology education courses three days one week and two days the next. The result is that the number of class meetings is equivalent to the number of days in one quarter, however those meetings are spread over the course of a semester.

Appendix B:

Consent Form

Consent to Participate In UW-Stout Approved Research

Title:
An analysis of the effects of convergent and divergent instructional methods on students' abilities to understand mechanisms

Investigator:
Joseph Rintelman
UW-Stout Graduate Student

Advisor:
Dr. Ken Welty
Professor – UW-Stout

Description of Study:
The purpose of this study is to compare two different approaches to teaching students about mechanisms.

The study will take place during class time and the concepts are in keeping with the current curriculum. Your child's participation in this study will in no way affect his or her grade.

This study is confidential, meaning that your child's name will not be included on any documents. Participation in the pre-test and post-test survey is voluntary. If at any time you choose to withdraw your student from the study, you may do so without any consequence.

This study has been reviewed and approved by The University of Wisconsin-Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies. If you have questions or concerns regarding this study please contact the Investigator or Advisor. If you have any questions, concerns, or reports regarding your child's rights as a research subject, please contact the IRB Administrator.

Investigator: Joseph Rintelman
(262) 502-7429, rintelmanj@uwstout.edu

Advisor: Dr. Ken Welty
(715) 232-1206, Weltyk@uwstout.edu

IRB Administrator
Sue Foxwell, Director, Research Services
152 Vocational Rehabilitation Bldg.
UW-Stout
Menomonie, WI 54751
715-232-2477
foxwells@uwstout.edu

Parental Statement of Consent:
Please Check one:

______ I give consent to allow my child to participate in this study

______ I do not give consent to allow my child to participate in this study

Child's Name: ____________________________________

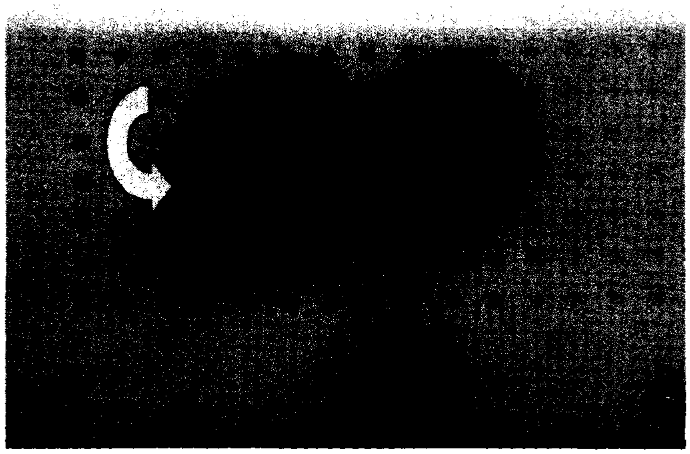
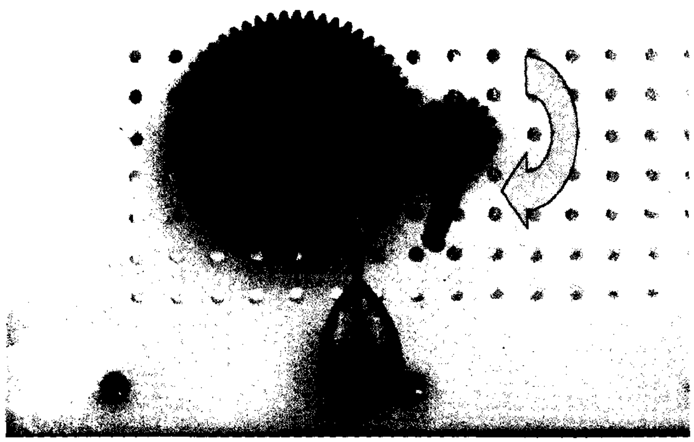
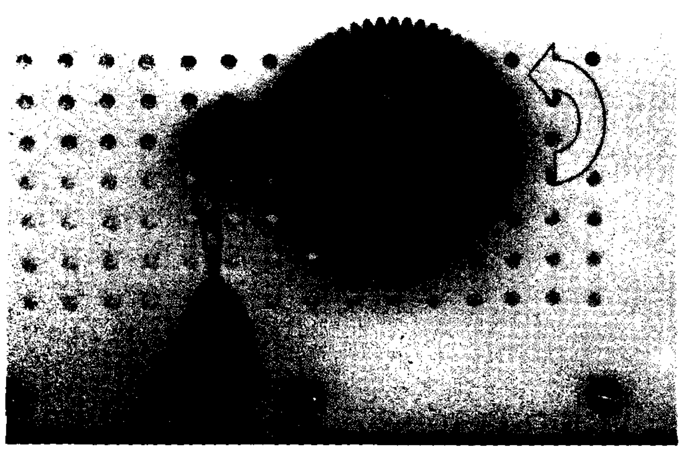
____ Date: ______________
Signature of parent or guardian

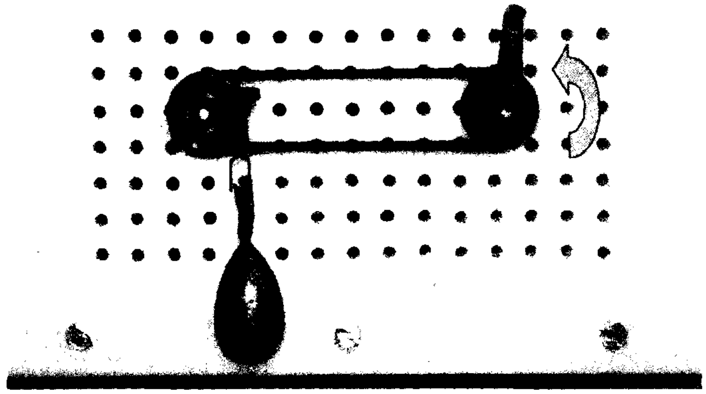
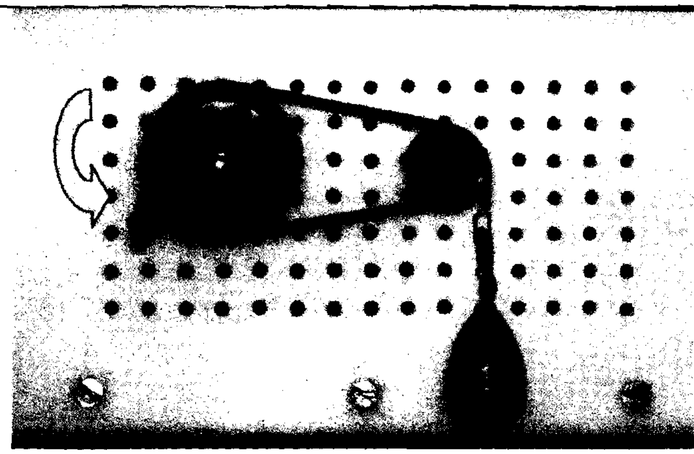
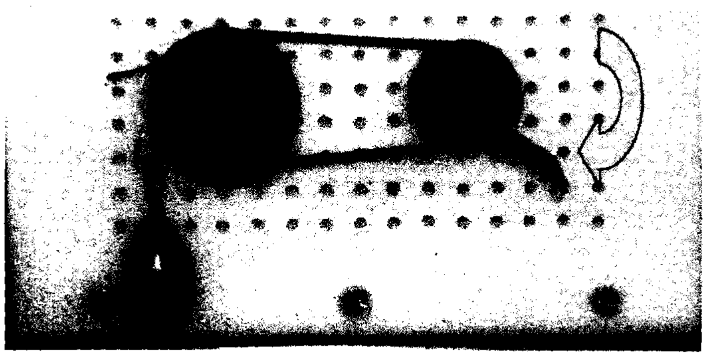
Participant Statement of Consent:
I have discussed my participation in this study with my parents, I understand my rights as a participant, and by signing the blank below I agree to participate in this study.

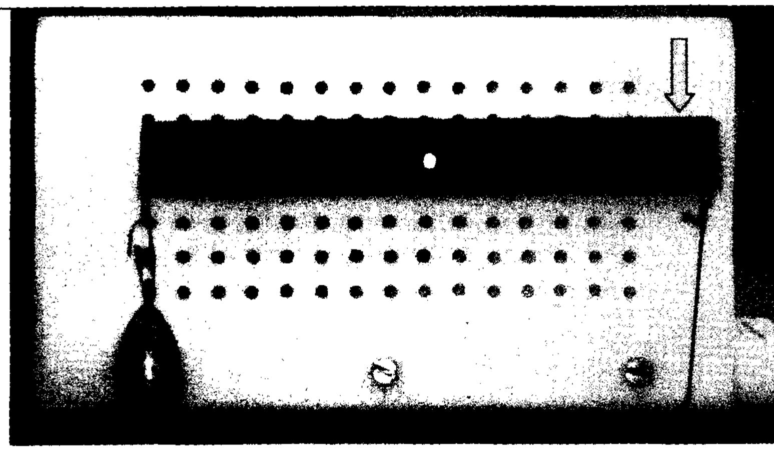
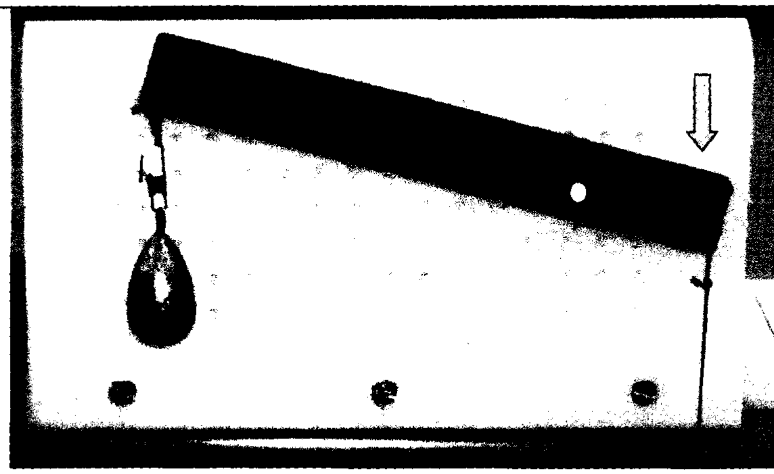
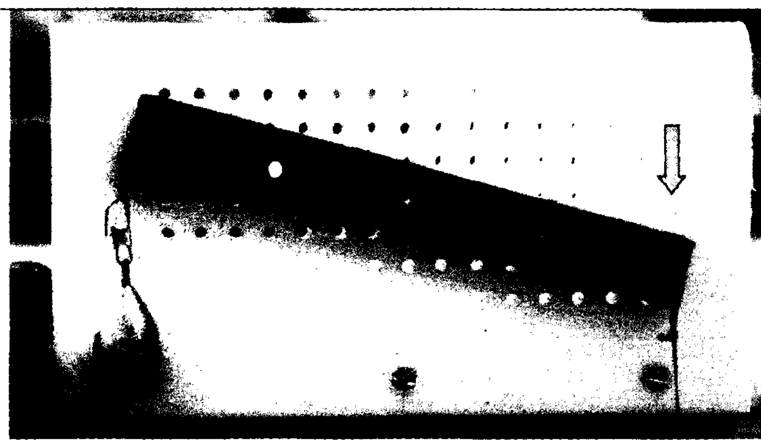
____ Date: ______________
Participant Signature (Child's signature)

Appendix C:

Pretest/Posttest Pictures

Gear as Balanced Mechanism	
Gear as Force Multiplier	
Gear as Distance Multiplier	

Belt & Pulley as Balanced Mechanism	
Belt & Pulley as Distance Multiplier	
Belt & Pulley as Force Multiplier	

Lever as Balanced Mechanism	
Lever as Distance Multiplier	
Lever as Force Multiplier	

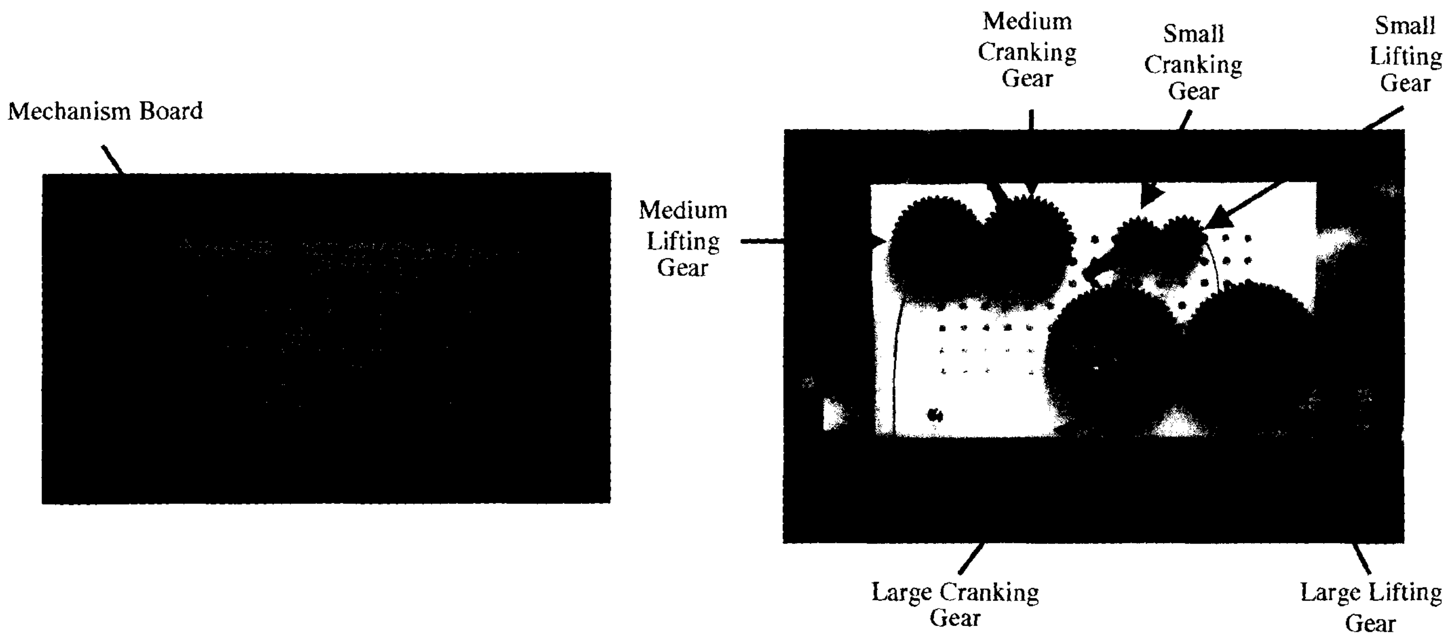
Appendix D:

Convergent Gear Laboratory Activity Packet

Gears

Today we are going to learn about gears and their attributes. Please follow the directions below and answer the corresponding questions.

Look at the picture below and notice the labels. These are the terms that will be used to describe the various parts throughout the activity.

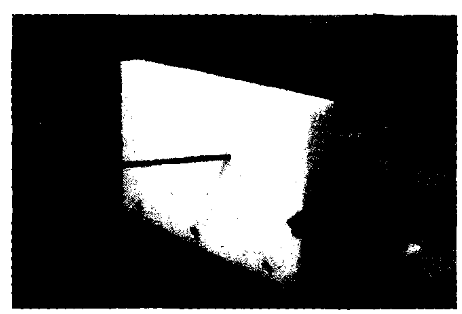


Gear Arrangement #1

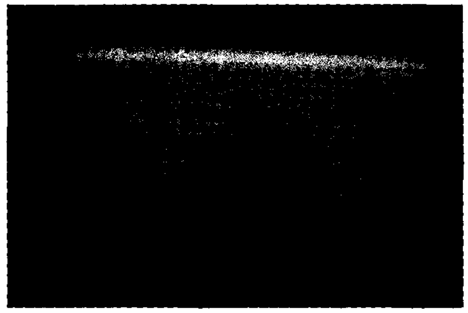
I. The first arrangement we will try is very straightforward.

a. Arrange the medium cranking gear and the medium lifting gear on the mechanism board so that their teeth mesh.

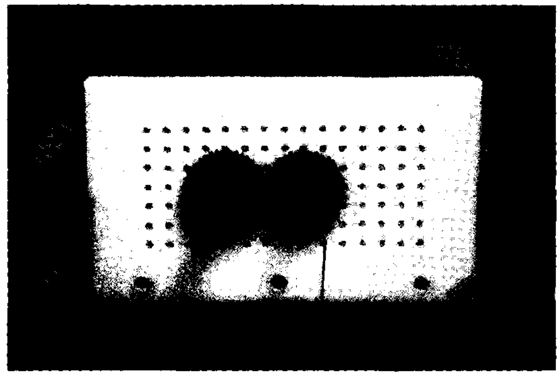
Insert the lifting gear into a hole on the mechanism board:



Insert cranking gear next to the lifting gear:



The gears should like this:

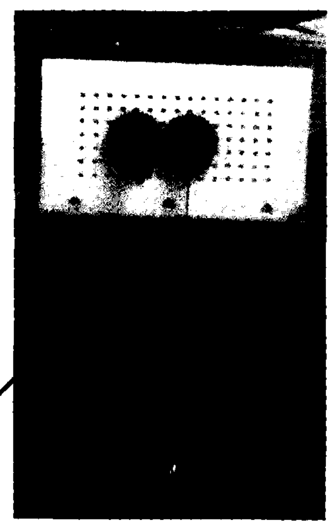


1. Turn the cranking gear two times around. How many times does the lifting gear turn? *(Circle correct answer)*
    a. Once
    b. Twice
    c. Three Times
    d. Four times

II. Now attach the weight to the string on the lifting gear.

Weight

Weight attached to string

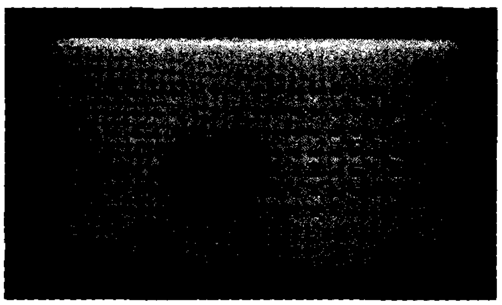


Final Set-Up

2. Turn the cranking gear until you have lifted the weight all the way up. How many times did you have to turn the cranking gear?
    a. One and a half
    b. Two and a half
    c. Three and a half
    d. Four and a half

3. Describe the amount of effort you are putting into turning the cranking gear
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

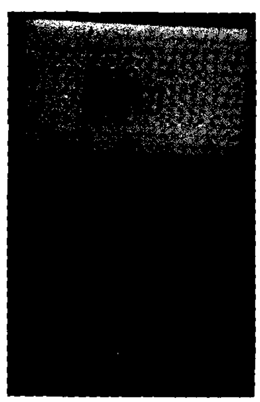
III. Remove the medium sized gears and insert the small cranking gear and small lifting gear so that their teeth mesh.



4. When you turn the cranking gear two times, how many times does the lifting gear turn?
    a. Once
    b. Twice
    c. Three Times
    d. Four Times

IV. Now attach the weight to the lifting gear string.

The gears should look like this:



5. Turn the cranking gear until you have lifted the weight all the way up. How many turns did it take you?
   a. Three
   b. Five
   c. Nine
   d. Twelve

6. Describe the amount of effort you are putting into turning the cranking gear
   a. More than the mass of the weight
   b. Less than the mass of the weight
   c. An amount equal to the mass of the weight

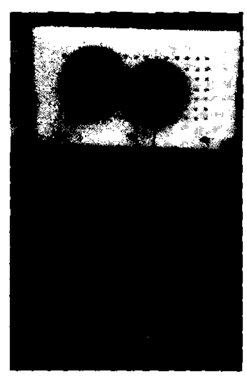
V. Now remove the small gears. Insert the large lifting and large cranking gear so that their teeth mesh.

The gears should look like this:

7. Turn the cranking gear two times around. How many times does the lifting gear turn?
   a. Once
   b. Twice
   c. Three Times
   d. Four Times

VI. Now attach the weight to the lifting gear string.

The gears should look like this:



8. Turn the cranking gear until you have lifted the weight all the way up. How many turns did it take you?
   a. Once
   b. One and a half times
   c. Three times
   d. Three and a half times

9. Describe the amount of effort you are putting into turning the cranking gear
   a. More than the mass of the weight
   b. Less than the mass of the weight
   c. An amount equal to the mass of the weight

Based on your experience above answer the following questions.

10. When the lifting gear and cranking gear are the same size, the number of turns made by the cranking gear is _____________ the number of times the lifting gear turns.

    a. Equal to
    b. Less than
    c. More than

11. When the lifting gear and cranking gear are the same size the amount of effort needed to lift something is ____________ the mass of the object being lifted.

    a. Equal to
    b. Less than
    c. More than

Input = *force put into cranking & number of times cranking gear was turned*
Output = *force used for lifting the weight & number of times lifting gear turned*

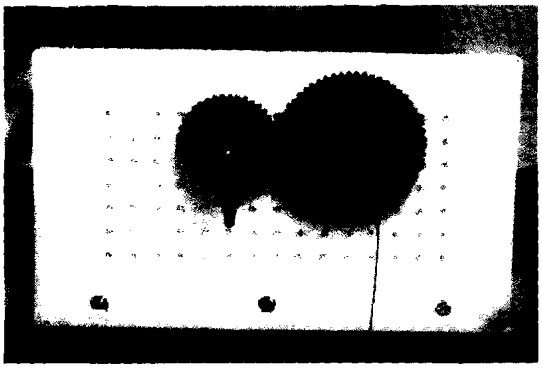
12. Based on the input and output experienced I would label this arrangement of gears as a:

    a. Distance Multiplier
    b. Force Multiplier
    c. Balanced Mechanism

Gear Arrangement #2

VII. This arrangement will use two different size gears.
   a. Arrange the medium cranking gear and the large lifting gear on the mechanism board so that their teeth mesh.

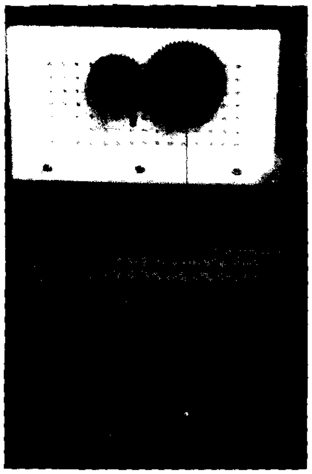
The gears should look like this:



13. Turn the cranking gear two times around. How many times does the lifting gear turn?
    a. 1 1/2 turns
    b. 2 1/2 turns
    c. 3 1/2 turns
    d. 4 1/2 turns

Now attach the weight to the string on the lifting gear.

The gears should look like this:

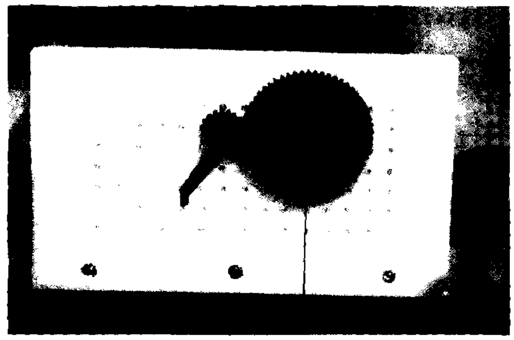


14. Turn the cranking gear until you have lifted the weight all the way up. How many turns did it take you?
    a. Two and one half
    b. Three and one half
    c. Four and one half
    d. Five and one half

15. Describe the amount of effort you are putting into turning the cranking gear
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

Remove the medium cranking gear and replace it with the small cranking gear.

The gears should look like this:



16. Turn the cranking gear two times around. How many times does the lifting gear turn?
    a. One Quarter of a turn
    b. One Half of a turn
    c. Three Quarters of a turn
    d. One full turn

Now attach the weight to the lifting gear.

The gears should look like this:

17. Turn the cranking gear until you have lifted the weight all the way up. How many turns did it take you?
    a. Two
    b. Three
    c. Four
    d. Five

18. Describe the amount of effort you are putting into turning the cranking gear. *(Spin it a few times to get a good feel)*

    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

Based on your experience above answer the following questions.

19. When the cranking gear is smaller than the lifting gear, the number of turns made by the cranking gear is ______________ the number of times the lifting gear turns.

    a. Equal to
    b. Less than
    c. More than

20. When the cranking gear is smaller than the lifting gear, the amount of effort needed to lift something is _____________ the mass of the object being lifted.

    a. Equal to
    b. Less than
    c. More than

<u>Input</u> = force put into cranking & number of times cranking gear was turned
<u>Output</u> = force used for lifting the weight & number of times lifting gear turned

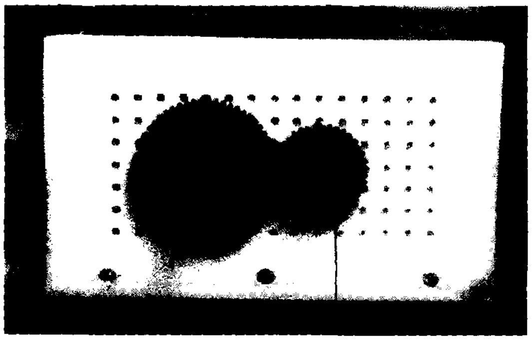
21. Based on the input and output experienced I would label this arrangement of gears as a:

    a. Distance Multiplier
    b. Force Multiplier
    c. Balanced Mechanism

<u>Gear Arrangement #3:</u>

This arrangement will use two different size gears.
- Arrange the large cranking gear and the medium lifting gear on the mechanism board so that their teeth mesh.

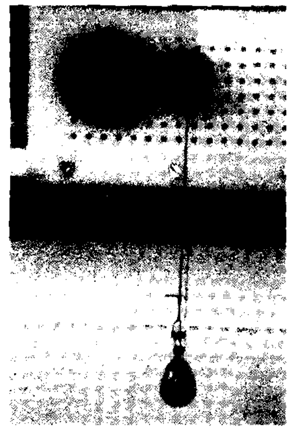
The gears should look like this:



22. Turn the cranking gear two times around. How many times does the lifting gear turn?
    a. Once
    b. Twice
    c. Three Times
    d. Four times

Now attach the weight to the string on the lifting gear.

This is what the gears should look like:

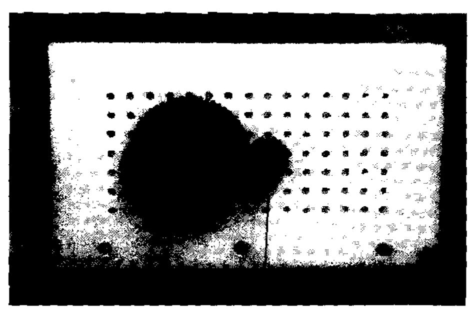


23. Turn the cranking gear until you have lifted the weight all the way up. How many turns did it take you?
    a. One and a half
    b. Two and a half
    c. Four and a half
    d. Five and a half

24. Describe the amount of effort you are putting into turning the cranking gear
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

Remove the medium lifting gear and replace it with the small lifting gear.

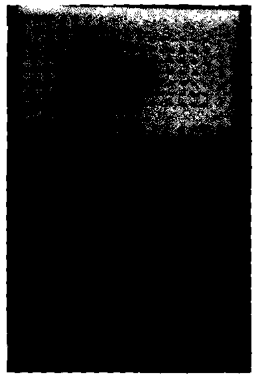
The gears should look like this:



25. Turn the cranking gear two times around. How many times does the lifting gear turn?
    a. Six times
    b. Seven times
    c. Eight times
    d. Nine times

Now attach the weight to the lifting gear.

The gears should look like this:



26. Turn the cranking gear until you have lifted the weight all the way up. How many turns did it take you?
    a. 1 1/2 turns
    b. 2 1/2 turns
    c. 3 1/2 turns
    d. 4 1/2 turns

27. Describe the amount of effort you are putting into turning the cranking gear
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

Based on your experience above answer the following questions.

28. When the craning gear is larger than the lifting gear, the number of turns made by the cranking gear is ____________ the number of times the lifting gear turns.

    a. Equal to
    b. Less than
    c. More than

29. When the cranking gear is larger than the lifting gear, the amount of effort needed to lift something is ____________ the mass of the object being lifted.

    a. Equal to
    b. Less than
    c. More than

Input = force put into cranking & number of times cranking gear was turned
Output = force used for lifting the weight & number of times lifting gear turned

30. Based on the input and output experienced I would label this arrangement of gears as a:

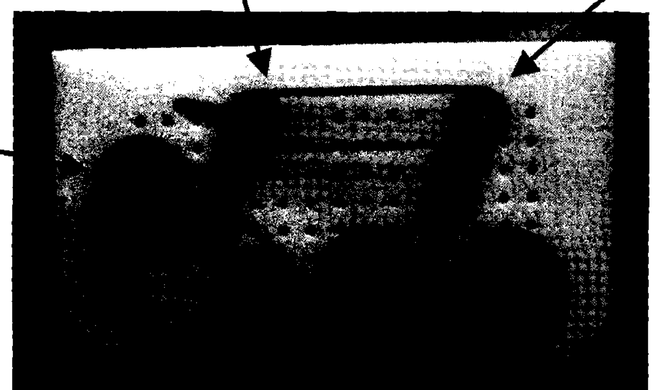
    a. Distance Multiplier
    b. Force Multiplier
    c. Balanced Mechanism

Appendix E:
Convergent Belt and Pulley Laboratory Activity Packet

Belts & Pulleys

Today we are going to learn about belts and pulleys and their attributes. Please follow the directions below and answer the corresponding questions.

Look at the picture below and notice the labels. These are the terms that will be used to describe the various parts throughout the activity.

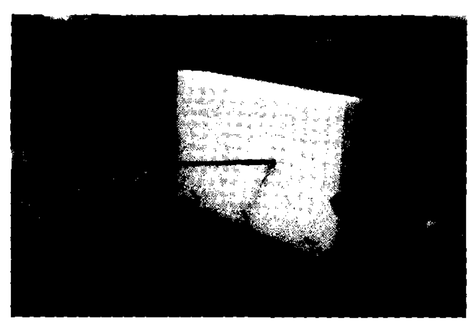


Pulley Arrangement #1

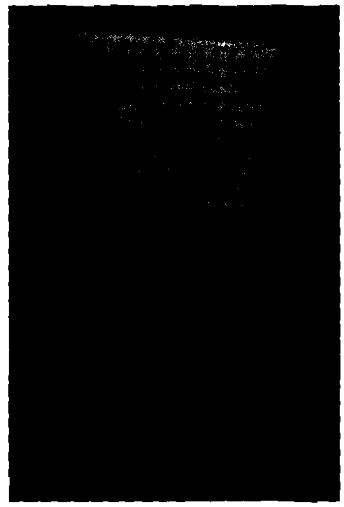
I. The first arrangement we will try is very straightforward.

b. Arrange the medium cranking pulley and the medium lifting pulley on the mechanism board so that they spin together.

Insert them medium lifting pulley into a hole on the mechanism board:

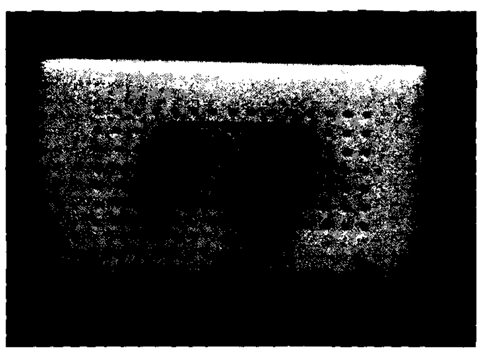


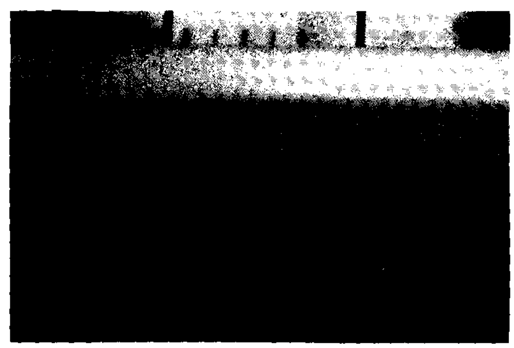
Slide belt onto lifting pulley:



Put cranking pulley through belt, pull tight, and insert into mechanism board as shown:

Once complete, the belt and pulley should look like this:



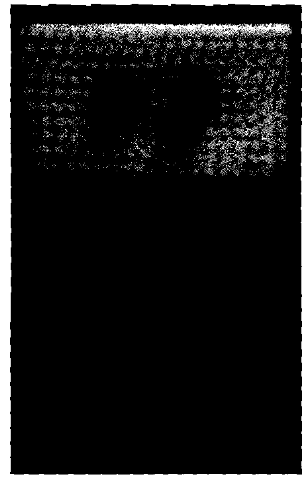


1. Turn the cranking pulley two times around. How many times does the lifting pulley turn? *(Circle correct answer)*
    a. Once
    b. Twice
    c. Three Times
    d. Four times

II. Now attach the weight to the string on the lifting pulley.

Weight

Weight attached to string



Final Set-Up

2. Turn the cranking pulley until you have lifted the weight all the way up. How many times did you have to turn the cranking pulley?
    a. 1 3/4 turns
    b. 2 3/4 turns
    c. 3 3/4 turns
    d. 4 3/4 turns

3. Describe the amount of effort you are putting into turning the cranking pulley
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

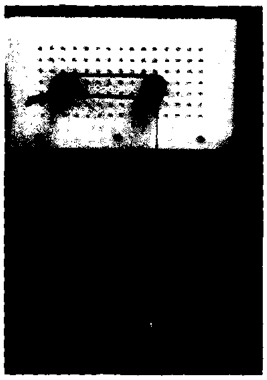
III. Remove the medium sized pulleys and insert the small cranking pulley and small lifting pulley so that they turn together.

The pulleys should look like this:

4. When you turn the cranking pulley two times, how many times does the lifting pulley turn?
    a. Once
    b. Twice
    c. Three Times
    d. Four Times

IV. Now attach the weight to the lifting pulley string.

The pulleys should look like this:

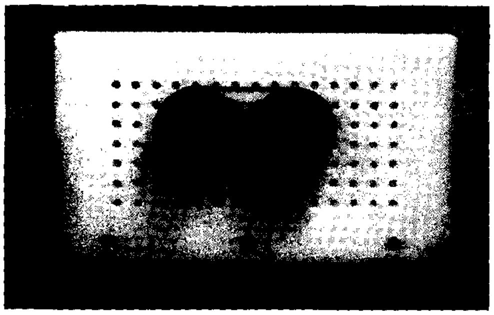


5. Turn the cranking pulley until you have lifted the weight all the way up. How many turns did it take you?
    a. One
    b. Two
    c. Three
    d. Four

6. Describe the amount of effort you are putting into turning the cranking pulley
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

V. Now remove the small pulleys. Insert the large lifting and large cranking pulley so that they turn together.

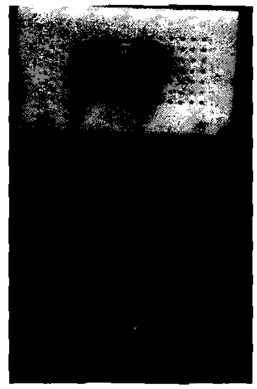
The pulleys should look like this:



7. Turn the cranking pulley two times around. How many times does the lifting pulley turn?
    a. Once
    b. Twice
    c. Three Times
    d. Four Times

VI. Now attach the weight to the lifting pulley string.

The pulleys should look like this:



8. Turn the cranking pulley until you have lifted the weight all the way up. How many turns did it take you?
    a. 1 3/4 turns
    b. 2 3/4 turns
    c. 3 3/4 turns
    d. 4 3/4 turns

9. Describe the amount of effort you are putting into turning the cranking pulley
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

Based on your experience above answer the following questions.

When the lifting pulley and cranking pulley are the same size, the number of turns made by the cranking pulley is ____________ the number of times the lifting pulley turns.

a. Equal to
b. Less than
c. More than

When the lifting pulley and cranking pulley are the same size the amount of effort needed to lift something is ____________ the mass of the object being lifted.

a. Equal to
b. Less than
c. More than

Input = *force put into cranking & number of times cranking pulley was turned*
Output = *force used for lifting the weight & number of times lifting pulley turned*
Based on the input and output experienced I would label this arrangement of pulleys as a:

a. Distance Multiplier
b. Force Multiplier
c. Balanced Mechanism

Pulley Arrangement #2

VII. This arrangement will use two different size pulleys.

c. Arrange the medium cranking pulley and the large lifting pulley on the mechanism board so that they turn together.

The pulleys should look like this:

10. Turn the cranking pulley two times around. How many times does the lifting pulley turn?
    a. One and a half
    b. Two and a half
    c. Three and a half
    d. Four and a half

VIII. Now attach the weight to the string on the lifting pulley.

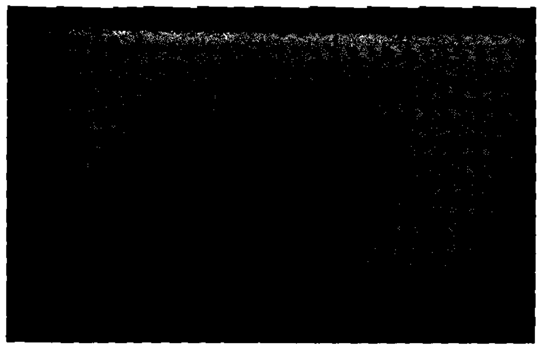
The pulleys should look like this:

11. Turn the cranking pulley until you have lifted the weight all the way up. How many turns did it take you?
    a. 1 1/2 turns
    b. 2 1/2 turns
    c. 3 1/2 turns
    d. 4 1/2 turns

12. Describe the amount of effort you are putting into turning the cranking pulley
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

IX. Remove the medium cranking pulley and replace it with the small cranking pulley.

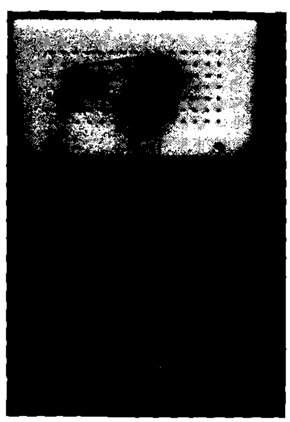
The pulleys should look like this:



13. Turn the cranking pulley two times around. How many times does the lifting pulley turn?
    a. Once
    b. Twice
    c. Three Times
    d. Four Times

X. Now attach the weight to the lifting pulley.

The pulleys should look like this:



14. Turn the cranking pulley until you have lifted the weight all the way up. How many turns did it take you?
    a. One
    b. Two
    c. Three
    d. Four

15. Describe the amount of effort you are putting into turning the cranking pulley
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

Based on your experience above answer the following questions.

When the cranking pulley is smaller than the lifting pulley, the number of turns made by the cranking pulley is ____________ the number of times the lifting pulley turns.

a. Equal to
b. Less than
c. More than

When the cranking pulley is smaller than the lifting pulley, the amount of effort needed to lift something is ___________ the mass of the object being lifted.

a. Equal to
b. Less than
c. More than

<u>Input</u> = force put into cranking & number of times cranking pulley was turned
<u>Output</u> = force used for lifting the weight & number of times lifting pulley turned
Based on the input and output experienced I would label this arrangement of pulleys as a:

a. Distance Multiplier
b. Force Multiplier
c. Balanced Mechanism

<u>Pulley Arrangement #3:</u>

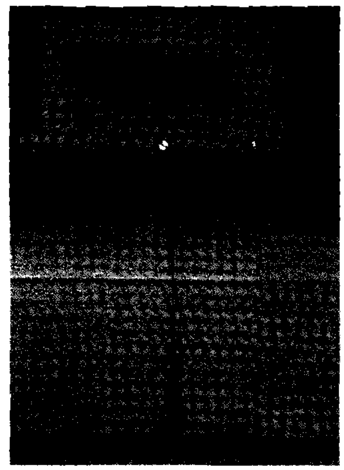
XI. **This arrangement will use two different size pulleys.**
    a. Arrange the medium cranking pulley and the small lifting pulley on the mechanism board so that they turn together.

The pulleys should look like this:

16. Turn the cranking pulley two times around. How many times does the lifting pulley turn?
    a. Once
    b. Twice
    c. Three Times
    d. Four times

XII. Now attach the weight to the string on the lifting pulley.

This is how the pulleys should look:

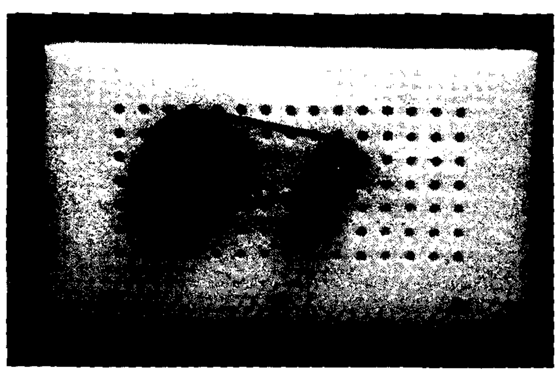


17. Turn the cranking pulley until you have lifted the weight all the way up. How many turns did it take you?
    a. Half of a turn
    b. One and a half turns
    c. Two and a half turns
    d. Three and a half turns

18. Describe the amount of effort you are putting into turning the cranking pulley
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

XIII. Remove the medium cranking pulley and replace it with the large lifting pulley.

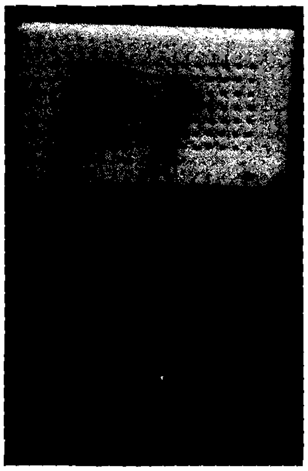
The pulleys should look like this:



19. Turn the cranking pulley two times around. How many times does the lifting pulley turn?
    a. Once
    b. Twice
    c. Three Times
    d. Four times

XIV. Now attach the weight to the lifting pulley.

The pulleys should look like this:



20. Turn the cranking pulley until you have lifted the weight all the way up. How many turns did it take you?
    a. One and a half
    b. Two and a half
    c. Three and a half
    d. Four and a half

21. Describe the amount of effort you are putting into turning the cranking pulley
    a. More than the mass of the weight
    b. Less than the mass of the weight
    c. An amount equal to the mass of the weight

Based on your experience above answer the following questions.

23. When the cranking pulley is larger than the lifting pulley, the number of turns made by the cranking pulley is _____________ the number of times the lifting pulley turns.

a. Equal to
b. Less than
c. More than

24. When the cranking pulley is larger than the lifting pulley, the amount of effort needed to lift something is ___________ the mass of the object being lifted.

a. Equal to
b. Less than
c. More than

<u>Input</u> = *force put into cranking & number of times cranking pulley was turned*
<u>Output</u> = *force used for lifting the weight & number of times lifting pulley turned*

25. Based on the input and output experienced I would label this arrangement of pulleys as a:

a. Distance Multiplier
b. Force Multiplier
c. Balanced Mechanism

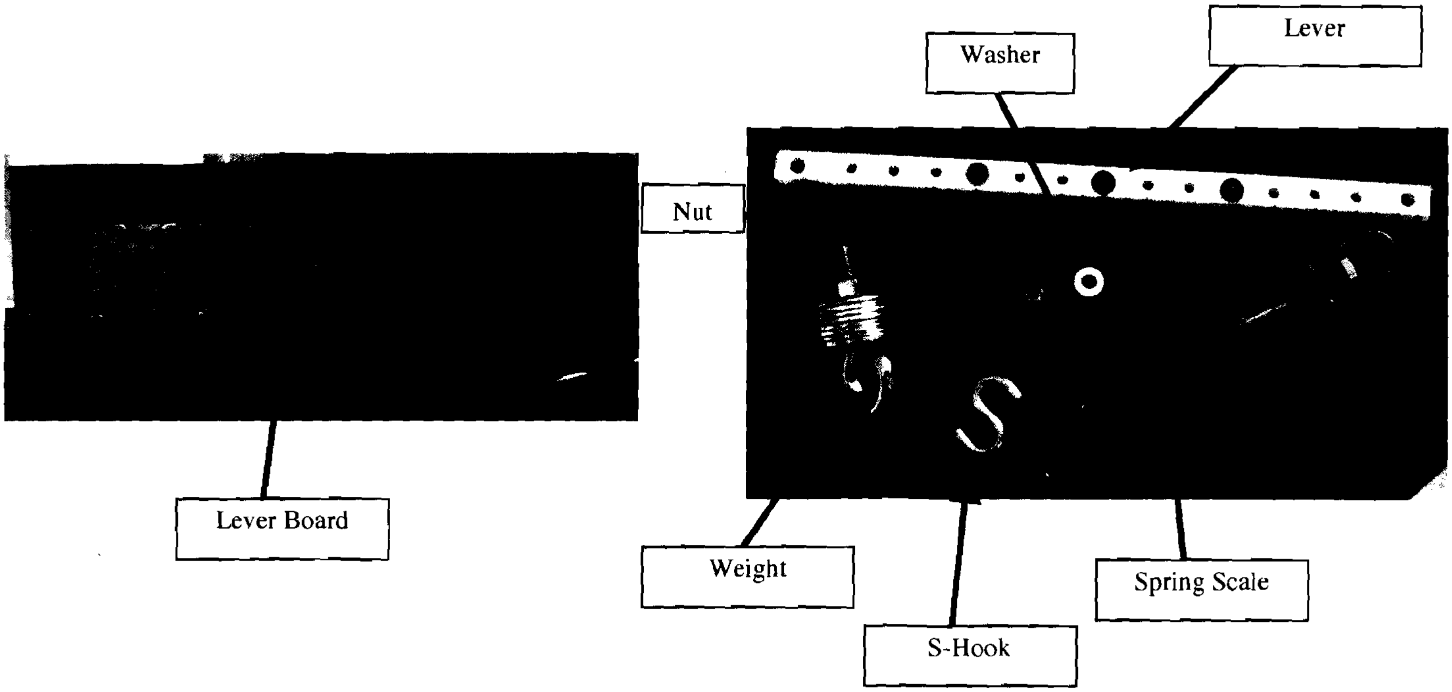
Appendix F:

Convergent Lever Laboratory Activity Packet

Levers

Today we are going to learn about levers and their attributes. Please follow the directions below and answer the corresponding questions.

Look at the picture below and notice the labels. These are the terms that will be used to describe the various parts throughout the activity.



Lever Arrangement #1

I. The first arrangement we will try is very straightforward.

a. Arrange the lever so that the bolt in the center of the lever board fits into the red hole on the lever.

Put the red hole onto the bolt:

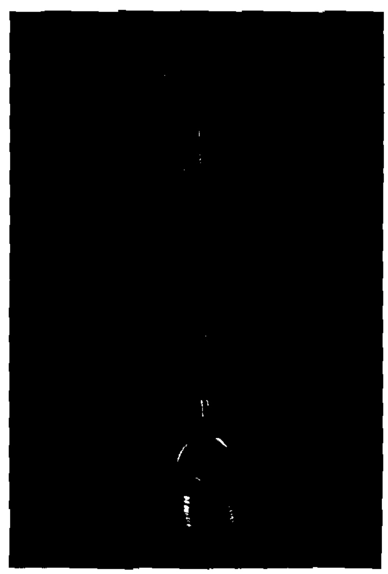
Attach the washer and nut:

The lever should like this:

1. Pull the right side of the lever down 1.5 inches. How high does the left side of the lever go? *(Circle correct answer)*
   d. 1/2 inch
   e. 1 inch
   f. 1.5 inches
   g. 2 inches

II. Now weigh the S-hook and weight with the spring scale.

This is how to weigh the weight:



2. What is the weight of the S-hook and weight?
    a. 2 N
    b. 3 N
    c. 4 N
    d. 5 N

III. Now attach the S-hook and weight to the left side of the lever and the spring scale to the right side of the lever.

The lever should look like this:

3. Pull the spring scale down about 1.5 inches and hold it there. How many Newtons of force are you using?
    a. 2 N
    b. 3 N
    c. 4 N
    d. 5 N

Based on your experience above answer the following questions.

When the pivot point of the lever is in the exact middle between the weight and spring scale the distance the right side travels is ___________ the distance the left side travels:

a. Equal to
b. Less than
c. More than

When the pivot point of the lever is in the exact middle between the weight and spring scale the amount of force needed to lift the weight is ___________ the mass of the weight itself.

a. Equal to
b. Less than
c. More than

Input = force put into lifting the weight and distance the lever traveled on the right side
Output = mass of the weight being lifted & distance the left side traveled
Based on the input and output experienced I would label this arrangement of a lever as a:

a. Distance Multiplier
b. Force Multiplier
c. Balanced Mechanism

Lever Arrangement #2

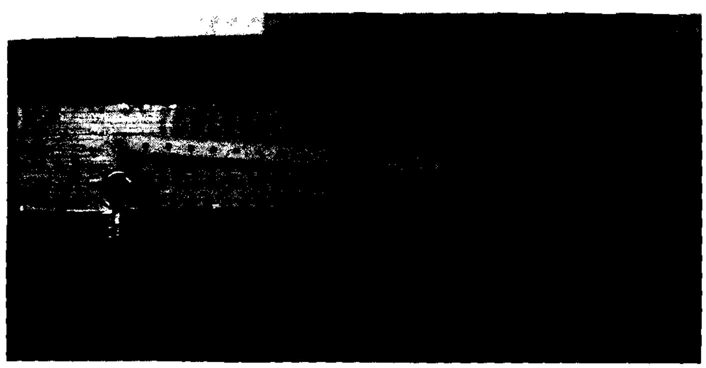
IV. **Arrange the lever so that the purple hole is inserted onto the bolt.**

The lever should look like this:

4. Pull the right side of the lever down 1 inch. How far does the left side travel?
   a. 1/2 inch
   b. 1 inches
   c. 1.5 inches
   d. 2 inches

V. **Now attach the weight & S-hook to the left side of the lever and the spring scale to the right side.**

The lever should look like this:



5. Pull the spring scale down about 1 inch and hold it there. Look at the spring scale, how many Newtons of force are you using to lift the weight?
    a. 8 N
    b. 10 N
    c. 12 N
    d. 14 N

Based on your experience above answer the following questions.

When the pivot point on the lever is closer to the right side, the distance the left side moves is ____________ the distance the right side moves.

a. Equal to
b. Less than
c. More than

When the pivot point on the lever is closer to the spring scale, the amount of force needed to lift the weight is ____________ the mass of the weight itself.

a. Equal to
b. Less than
c. More than

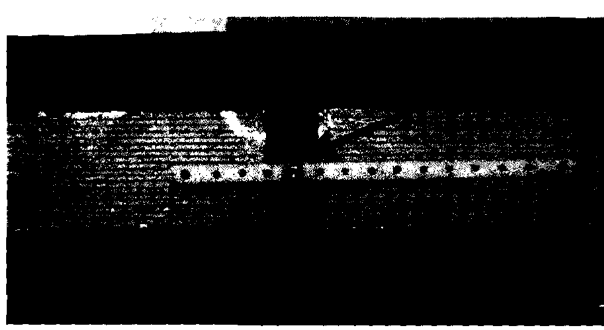
Input = force put into lifting the weight and distance the lever traveled on the right side
Output = mass of the weight being lifted & distance the left side traveled
Based on the input and output experienced I would label this arrangement of levers as a:

a. Distance Multiplier
b. Force Multiplier
c. Balanced Mechanism

Lever Arrangement #3:

VI. Attach the lever so that the Yellow colored hole is inserted onto the bolt.

The lever should look like this:



Yellow Hole

6. Move the right side of the lever down 2 inches. How far did the left side of the lever travel?
    a. 1/2 inch
    b. 1 inch
    c. 1.5 inches
    d. 2 inches

VII. Now attach the S-hook and weight to the left side of the lever and the spring scale to the right side.

The lever should look like this:

7. Pull the spring scale down 2 inches and hold it there. How many Newtons of force are you using to lift the weight?

    a. .5 N
    b. 1.5 N
    c. 2.5 N
    d. 3.5 N

Based on your experience above answer the following questions by circling the best answer.

When pivot point of the lever is closer to the left side of the lever, the distance the right side moves is ______________ the distance the left side moves.

a. Equal to
b. Less than
c. More than

When the pivot point of the lever is closer to the left side of the lever, the amount of force applied to lifting the weight is ______________ the mass of the weight itself.

a. Equal to
b. Less than
c. More than

<u>Input</u> = force put into lifting the weight and distance the lever traveled on the right side
<u>Output</u> = mass of the weight being lifted & distance the left side traveled
Based on the input and output experienced I would label this arrangement of levers as a:

a. Distance Multiplier
b. Force Multiplier
c. Balanced Mechanism

Appendix G:

Divergent Gear Laboratory Activity Packet

Gear Design Problem

<u>Trial #1:</u>

- Your task is to arrange the materials you were given in order to lift the weight.
- Specifically you must:
    - Bring the weight up in 3.5 or less turns on the cranking gear.
    - You must use two different size gears
- *Important:*
    - ***Before you begin to use the materials, you <u>must</u> sketch an idea on paper in the boxes below.***
    - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***
    - ***Your sketch must clearly show the size of the gears being used as well as which is the cranking gear and which is the lifting gear.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:

What is the relationship between the number of turns you made on the cranking gear and the number of turns made by the lifting gear?

Do you think that you are applying more effort, less effort, or an equal amount of effort to turning the cranking gear as compared to the mass of the weight?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

<u>Trial #2 Criteria:</u>

- Your task is to arrange the materials you were given in order to lift the weight.
- The arrangement must meet the following criteria
  - The number of turns the cranking gear and lifting gear make must be equal
  - The force needed to lift the weight should not exceed the mass of the weight
- *Important:*
  - ***Before you begin to use the materials, you <u>must</u> sketch an idea on paper in the boxes below.***
  - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***
  - ***Your sketch must clearly show the size of the gears being used as well as which is the cranking gear and which is the lifting gear.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:
What is the relationship between the size of the cranking gear and the size of the lifting gear?

Do you think that you are applying more effort, less effort, or an equal amount of effort to turning the cranking gear as compared to the mass of the weight?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

<u>Trial #3 Criteria:</u>

- Your task is to arrange the materials you were given in order to lift the weight.
- The following criteria must be met:
  - The effort or force used on the cranking gear must be less than the mass of the weight.
  - The number of turns made with the cranking gear is not important.
  - You must use two different sized gears
- *Important:*
  - ***Before you begin to use the materials, you <u>must</u> sketch an idea on paper in the boxes below.***
  - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***
  - ***Your sketch must clearly show the size of the gears being used as well as which is the cranking gear and which is the lifting gear.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:
What is the relationship between the number of turns you made on the cranking gear and the number of turns made by the lifting gear?

Do you think that you are applying more effort, less effort, or an equal amount of effort to turning the cranking gear as compared to the mass of the weight?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

Appendix H:

Divergent Belt and Pulley Laboratory Activity Packet

Belt & Pulley Design Problem:

<u>Belt & Pulley Problem #1:</u>

- Your task is to arrange the materials you were given in order to lift the weight.
- For this problem the following criteria must be met:
  - The number of turns the cranking pulley and lifting pulley make must be equal.
  - The amount of force the user puts into turning the belt and pulley should not exceed the mass of the weight.
- *Important:*
  - ***Before you begin to use the materials, you <u>must</u> sketch an idea on paper in the boxes below.***
  - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***
  - ***Your sketch must clearly show the size of the pulleys being used as well as which is the cranking pulley and which is the lifting pulley.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:
What is the relationship between the size of the cranking pulley and the size of the lifting pulley?

Do you think that you are applying more effort, less effort, or an equal amount of effort to turning the cranking pulley as compared to the mass of the weight?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

Belt & Pulley Problem #2:

- Your task is to arrange the materials you were given in order to lift the weight.
- The following criteria must be met:
  - The weight must be lifted in 3 turns or less on the cranking pulley
  - You must use two different sized pulleys
  - The amount of force used is not a concern.
- *Important:*
  - ***Before you begin to use the materials, you must sketch an idea on paper in the boxes below.***
  - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***
  - ***Your sketch must clearly show the size of the pulleys being used as well as which is the cranking pulley and which is the lifting pulley.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:
What is the relationship between the number of turns you made on the cranking pulley and the number of turns made by the lifting pulley?

Do you think that you are applying more effort, less effort, or an equal amount of effort to turning the cranking pulley as compared to the mass of the weight?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

Belt & Pulley Problem #3:

- Your task is to arrange the materials you were given in order to lift the weight.
- The following criteria must be met:
  - The amount of force needed to turn the cranking pulley must be less than the mass of the weight
  - The number of turns made by the cranking gear is not important
  - You must use two different sized pulleys
- *Important:*
  - ***Before you begin to use the materials, you must sketch an idea on paper in the boxes below.***
  - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***
  - ***Your sketch must clearly show the size of the pulleys being used as well as which is the cranking pulley and which is the lifting pulley.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:

What is the relationship between the number of turns you made on the cranking pulley and the number of turns made by the lifting pulley?

Do you think that you are applying more effort, less effort, or an equal amount of effort to turning the cranking pulley as compared to the mass of the weight?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

Appendix I:

Divergent Lever Laboratory Activity Packet

Lever Design Problem:

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:

What is the relationship between the amount of force you used to lift the lever and the mass of the weight?

What is the relationship between the distance the lever traveled on the lifting side and the distance the lever traveled on the weight side?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

<u>Lever Problem #2:</u>

- Your task is to arrange the materials you were given in order to lift the weight.
- Specifically you must:
  - Create a mechanism that will allow the weight to be lifted 2 inches with input force only being 1 inch.
  - The amount of force used is not a concern.
- *Important:*
  - ***Before you begin to use the materials, you <u>must</u> sketch your idea on paper in the boxes below.***
  - ***Be sure to label which color hole you intend to use as the pivot point.***
  - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:

What is the relationship between the amount of force you used to lift the lever and the mass of the weight?

What is the relationship between the distance the lever traveled on the lifting side and the distance the lever traveled on the weight side?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

Lever Problem #3:

- Your task is to arrange the materials you were given in order to lift the weight.
- Specifically you must:
    - Create a lever that uses a lifting force which is equal to the mass of the weight itself
    - The distance over which the force is applied must be equal to the distance the weight moves.
- *Important:*
    - ***Before you begin to use the materials, you must sketch your idea on paper in the boxes below.***
    - ***Be sure to label which color hole you intend to use as the pivot point.***
    - ***If the first try is unsuccessful, sketch another idea and try that. Continue doing this until you have a successful solution.***

Arrangement #1:

Use this box to sketch your idea

Arrangement #2:

Use this box to sketch your idea

Arrangement #3:

Use this box to sketch your idea

Arrangement #4:

Use this box to sketch your idea

Arrangement #5:

Use this box to sketch your idea

Arrangement #6:

Use this box to sketch your idea

Arrangement #7:

Use this box to sketch your idea

Arrangement #8:

Use this box to sketch your idea

Once you have your final solution answer the following:

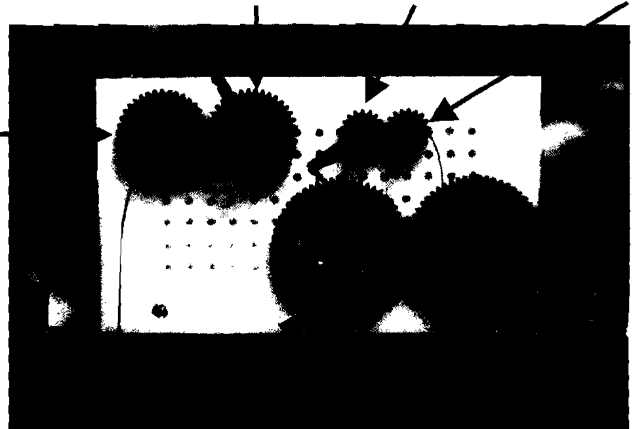
What is the relationship between the amount of force you used to lift the lever and the mass of the weight?

What is the relationship between the distance the lever traveled on the lifting side and the distance the lever traveled on the weight side?

How would you describe this arrangement of mechanisms, or what kind of label would you give it?

Appendix J:

Materials provided for gear laboratory activities

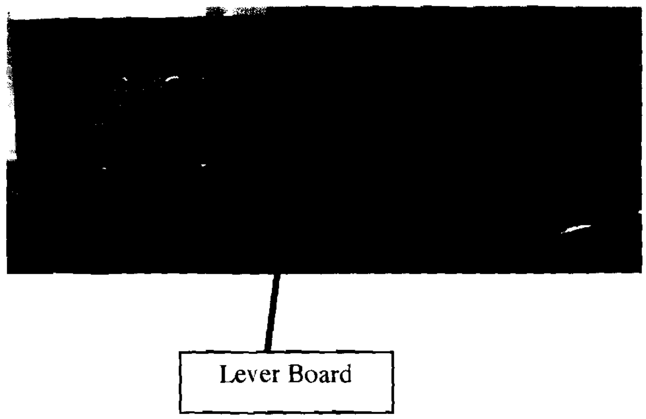


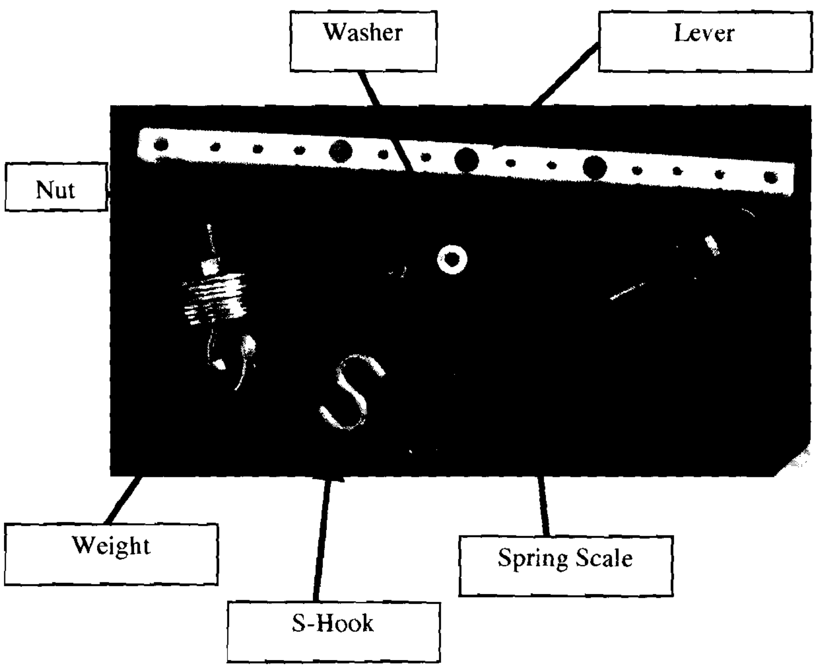
Appendix K:

Materials provided for belt and pulley laboratory activities

Appendix L:

Materials provided for lever laboratory activities





Appendix M:

Pictures of snacks used to illustrate sorting process

Appendix N:

Checklist for analyzing pretest/posttest

Student Name: ___________ **Pre-Test**

	Trial #1 Check One			**Trial #2 Check One**		
	Sorted based on a Physical Attribute	**Sorted using some other Criteria**	**Sorted based on Theoretical Function**	**Sorted based on a Physical Attribute**	**Sorted using some other Criteria**	**Sorted based on Theoretical Function**
Balanced Gear Picture						
Distance Multiplier Gear Picture						
Force Multiplier Gear Picture						
Balanced Lever Picture						
Distance Multiplier Lever Picture						
Force Multiplier Lever Picture						
Balanced Belt & Pulley Picture						
Distance Multiplier Belt & Pulley Picture						
Force Multiplier Belt & Pulley Picture						
Totals:						

Post-Test

	Trial #1 Check One			Trial #2 Check One		
	Sorted based on a Physical Attribute	**Sorted using some other Criteria**	**Sorted based on Theoretical Function**	**Sorted based on a Physical Attribute**	**Sorted using some other Criteria**	**Sorted based on Theoretical Function**
Balanced Gear Picture						
Distance Multiplier Gear Picture						
Force Multiplier Gear Picture						
Balanced Lever Picture						
Distance Multiplier Lever Picture						
Force Multiplier Lever Picture						
Balanced Belt & Pulley Picture						
Distance Multiplier Belt & Pulley Picture						
Force Multiplier Belt & Pulley Picture						
Totals:						

Appendix O:

Checklist for analyzing convergent lab activity performance

Convergent Gear Analysis

Question Number	**Check One**			**Check the Answer Chosen by the Student if Applicable**			
	Question Completed Correctly	Question Completed Correctly	Question Completed Correctly	A	B	C	D
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

Convergent Belt & Pulley Analysis

Question Number	**Check One**			**Check the Answer Chosen by the Student if Applicable**			
	Question Completed Correctly	Question Completed Correctly	Question Completed Correctly	A	B	C	D
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

Convergent Lever Analysis							
	Check One			**Check the Answer Chosen by the Student if Applicable**			
Question Number	Completed Question Correctly	Completed Question Correctly	Completed Question Correctly	A	B	C	D
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

Appendix P:

Checklist for analyzing divergent lab activity performance

Student Name: ______________________________

Design Problem Assessment

	Check One		**Check One**		**Check One**				**Complete**
	Completed Problem	Did Not Complete Problem	Created a Correct Solution	Created an Incorrect Solution	? #	Articulated Under-standing	Did Not Articulate Under-standing	No Attempt Made	Number of Iterations
Gear Problem #1					1				
					2				
					3				
Gear Problem #2					1				
					2				
					3				
Gear Problem #3					1				
					2				
					3				
Belt & Pulley Problem #1					1				
					2				
					3				
Belt & Pulley Problem #2					1				
					2				
					3				
Belt & Pulley Problem #3					1				
					2				
					3				
Lever Problem #1					1				
					2				
					3				
Lever Problem #2					1				
					2				
					3				
Lever Problem #3					1				
					2				
					3				

Appendix Q:

Responses to Questions during Activities

Question: I don't get what they want me to do? (Lever)
Answer: It is asking you to lift the weight (point to it) using the lever (point to it). How can you arrange the lever on lever board to lift that weight?
Question: I still don't get it.
Answer: So, if you were given this lever and this weight and told to lift the weight using the lever how would you arrange it? (Wait for answer) Okay, now you need to do that, only you need to attach the lever to the board. How could you attach that lever to the board? (Wait for answer) Good, now give that a try.

Question: What is a Newton?
Answer: A Newton is a way of measuring mass. Your scale shows a g and an N, which do you think you will be using?

Question: How do I keep track of how far I am moving the lever?
Answer: Draw the student's attention to the scale attached to the mechanism board.
Question: I still don't get it.
Answer: Ask the student what the measurement on the left side reads. Then ask the student what the measurement on the right side reads. If they are reading it incorrectly, demonstrate the proper way to read the scale.

Question: I don't get what they mean by turning the cranking gear (pulley) and counting the number of times the lifting gear (pulley) turns?
Answer: Can you point to the cranking gear? Which one is the lifting gear? Okay, I will turn the cranking gear and count my turns. You watch the lifting gear and count how many times it turns.

Question: Can we use more than two gears or pulleys?
Answer: You need to come up with a solution that meets the criteria of the problem presented.

Question: I don't get what they want me to do (Pulley or Gear Design Activity)
Answer: Did you read the directions? (Pause for response) Alright, then you need to create a system, using the materials you have been given (point to bag) that meets the criteria of the problem in your packet (point out criteri

Appendix R:

Directions for Pretest/Posttest Administration

<u>Trial #1</u>

1. Show video
2. Make sure all students have writing utensil, hand out as needed.
3. Things to tell students before handing out the first envelope:
   a. The arrows on the pictures are to show direction only, they cannot be used as a characteristic for sorting the pictures
   b. Wait until everyone is given their materials to start the process
   c. When done put all contents back in the envelope, it is not necessary to seal envelope
   d. Sit quietly and wait until teacher collects materials
4. Collect the envelopes from the students and put back into container labeled Trial #1

<u>For Trial #2</u>

1. Repeat the information from number 3 above.
2. Remind them that they must use a different defining characteristic than in Trial #1
3. This time they can start as soon as they receive their packet
4. When everyone is done, collect the materials and put into container labeled Trial #2
5. Collect all pencils that were lent out

<u>During the Process you may be asked the following questions, and these are good responses:</u>

- Do we have to sort them into three groups of three
  - Answer: Sort them into three groups
- What do we call these? Or how do I describe these?
  - Answer: Refer to them anyway you can think of that makes sense to you

<u>Other Notes:</u>

Indicate on the class roster sheet if anyone was missing